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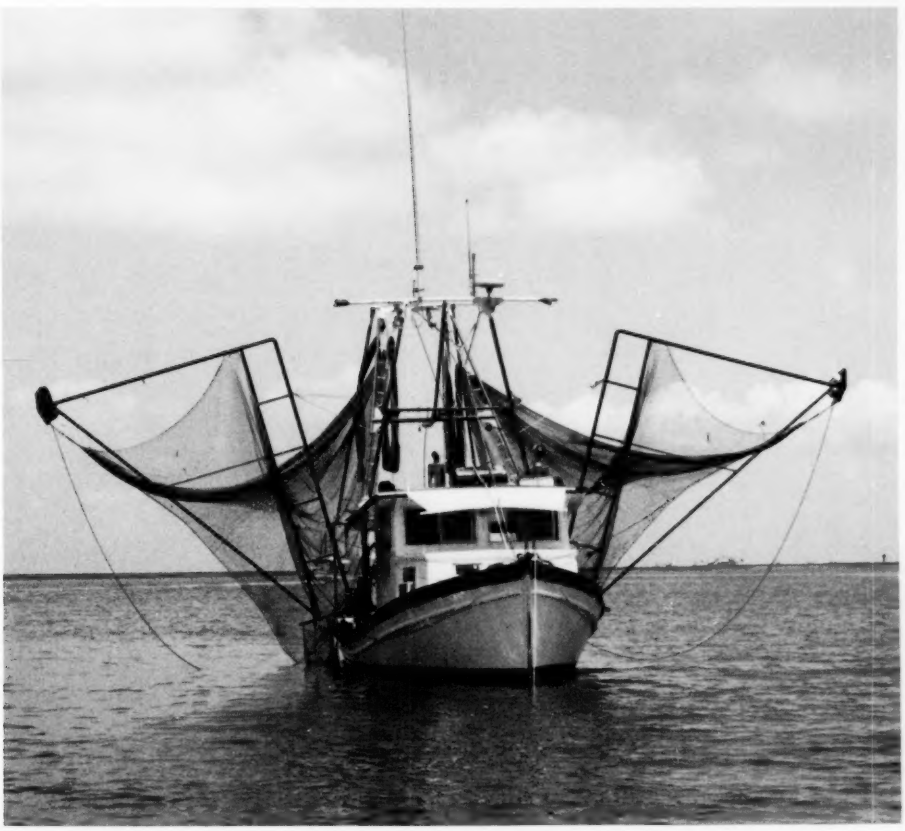

The Skimmer Net

Marine Fisheries REVIEW

On the cover: a vessel using a skimmer net. Photo by Stephen Hein, Louisiana Department of Wildlife and Fisheries.

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Species Trends in Sport Fisheries, Monterey Bay, Calif., 1959–86 — *Janet E. Mason* **1**

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Species Trends in Sport Fisheries, Monterey Bay, Calif., 1959–86

JANET E. MASON

Introduction

The Monterey Bay region of California (Fig. 1) has been the site of a recreational fishery for at least a century (Young, 1969). Skiff, pier, and shore-based fishing have long been present, and since the late 1920's, commercial passenger fishing vessels (CPFV's) have provided recreational fishing for rockfish in this region (Clark and Croaker, 1933). Starting in 1958, the region's recreational fisheries have been the subject of the most extensive catch surveys in California (Miller and Gotshall, 1965; Miller and Geibel, 1973; Miller et al.[1]). From 1958 to 1961 this region, comprising only 9% of the central and northern California coastline, was the site of 30% of its marine recreational fishing effort (Miller and Gotshall, 1965). Although shore and pier-based fishing received the most angler days of fishing in that period, bottom fishing from boats had the highest catch rates (>1 fish per hour).

Two modes of recreational fishing are now conducted from boats: CPFV and skiff fishing. Both fisheries rely heavily on an inshore assemblage of about 30 species caught over fairly shallow rock outcroppings (Miller et al.[1]). Rockfishes, *Sebastes* spp., constituted the most frequently caught species group, and in the 1960 CPFV fishery they contributed 85% of the fish caught from central and northern California (Miller and Gotshall, 1965). In the 1959 skiff fishery, rockfish contributed 54% of the fish caught. White croaker, *Genyonemus lineatus*, and flatfishes of various genera, caught over sandy sea floors, contributed 16% and 8% of the skiff catch (Miller and Gotshall, 1965). Rockfish caught from CPFV's and skiffs accounted for 74% and 20%, respectively, of the rockfish caught in all recreational fisheries for 1959–61 from central and northern California (Miller and Geibel, 1973). Thus the CPFV and skiff fisheries are the principal recreational fisheries harvesting rockfish in this region, and rockfish are the most important species group to these fisheries.

The inshore assemblage of fishes in the Monterey Bay region is composed of many different species including at least 25 species of rockfishes, and several of these species can be categorized into groups by their characteristic depths. The principal rockfishes taken in this region at shallow depths are blue, *Sebastes mystinus*; olive, *S. serranoides*; kelp, *S. atrovirens*; black, *S. melanops*; brown, *S. auriculatus*; and gopher, *S. carnatus*, rockfish (Miller and Geibel, 1973). There appears to be a change in species composition at about 70–75 m in central California, and Miller and Geibel (1973) found yellowtail rockfish, *S. flavidus*; bocaccio, *S. paucispinis*; chilipepper, *S. goodei*; widow rockfish, *S. entomelas*; greenspotted rockfish, *S. chlorostictus*; rosy rockfish, *S. rosaceus*; and starry rockfish, *S. constellatus*, were the principal species caught by anglers at greater depths. Lingcod, *Ophiodon elongatus*, are taken by recreational anglers mostly in rocky areas <70 m deep, although they are also taken in commercial trawls at greater depths.

Assembling data from several surveys into a time series provides a way to examine trends in relative abundance of key species over an extended period. Species composition in the skiff and CPFV fisheries of the Monterey Bay region has previously been examined only for isolated years (Miller and Gotshall, 1965; Holliday, 1984) or for periods of a few years (Miller and Geibel, 1973; Reilly et al.[2]). In commercial fisheries, as targeted stocks decline due to exploitation, fishing boats with more power or technology often move

[1] Miller, D. J., M. W. Odemar, and D. W. Gotshall. 1967. Life History and catch analysis of blue rockfish (Sebastodes mystinus) off central California, 1961–1965. Calif. Dep. Fish Game, Mar. Res. Off. Ref. 67-14, 130 p.

Janet E. Mason is with the Pacific Fisheries Environmental Group, Southwest Fisheries Science Center, National Marine Fisheries Service, NOAA, 1352 Lighthouse Ave., Pacific Grove, CA 93950.

ABSTRACT—Three surveys spanning 28 years were examined for changes in species caught by recreational fishermen from small boats (skiffs) and commercial passenger fishing vessels (CPFV's) in California's Monterey Bay region. As fishing effort increased, the catch of certain nearshore species of rockfish, Sebastes *spp., declined. CPFV fishing was conducted farther from port and in deeper water to compensate for declining abundance while most skiffs remained in traditional areas close to port. The trend toward deeper water CPFV fishing has been interrupted only temporarily by increased availability of nearshore species. Life history characteristics of rockfish including residential behavior, variable recruitment, and natural longevity contribute to a vulnerability to localized overfishing for several species.*

[2] Reilly, P. N., D. Wilson-Vandenberg, D. L. Watters, J. E. Hardwick, and D. Short. 1993. On board sampling of the rockfish and lingcod commercial passenger fishing vessel industry in northern and central California, May 1987 to December 1991. Calif. Dep. Fish Game, Mar. Res. Div. Admin. Rep. 93-4, 242 p.

to other stocks (Deimling and Liss, 1994). The same is true in recreational fisheries within the confines of acceptable on-board travel time. Examining the catch in subareas of the region and comparing skiff with CPFV catches reveals changes in locations and depths fished by CPFV's to compensate for declining catches near port.

Methods

Commercial passenger fishing vessels and skiffs share similar fishing techniques and catch many of the same species. CPFV's are operated by hired skippers, charge fees to take passengers fishing, and may be open to the public or chartered by groups. Skiffs include both privately owned boats launched from trailers at launch ramps and small boats rented for the day with or without outboard motors. Bottom fishing is the most common fishing technique of both skiffs and CPFV's in the Monterey Bay region, and only bottom fishing is included in this report. In bottom fishing, the boat does not move under its own power while fishing, and fish are taken from the surface and mid-depths as well as from the bottom. Trolling, fishing while the engine is moving the boat, is conducted primarily for Pacific salmon, *Oncorhynchus* spp., in northern California, and makes up a small percentage (0.7% for 1959–86) of the total catch per year in the Monterey Bay region, and is not covered in this report.

The Monterey Bay region extends from Point Año Nuevo (lat. 37° 07"N, long. 122° 20"W) to Point Sur (lat. 36° 18"N, long. 121° 54"W) (Fig. 1), and represents the maximum distance traveled by CPFV's from the ports of Santa Cruz and Monterey. Santa Cruz CPFV's generally fished in the northern area, from the edge of the Monterey Submarine Canyon north to Point Año Nuevo. CPFV's from Monterey fished the southern area from the edge of the Monterey Submarine Canyon, around the Monterey Peninsula to Carmel Bay, and south to Pt. Sur (Miller and Geibel, 1973). Skiffs, restricted by rough seas, longer travel times, and smaller gas tanks, fished a more limited area. In the Santa Cruz area in 1964, skiffs were launched from ramps at Santa Cruz harbor and Capitola or were rented from fishing shops on the piers or in the harbor, and 95% of the fishing was conducted within 7 km north or south of Santa Cruz harbor (Fig. 1). In Monterey in the same year, skiffs were launched or rented at the Monterey harbor and at Lovers Point in Pacific Grove, and 90% of the skiffs fished between Monterey and Point Piños (Miller et al.[1]). Larger boats and larger engines have extended the range of skiffs in later years, but most of the Monterey skiff fishing is still concentrated between Monterey and Cypress Point.

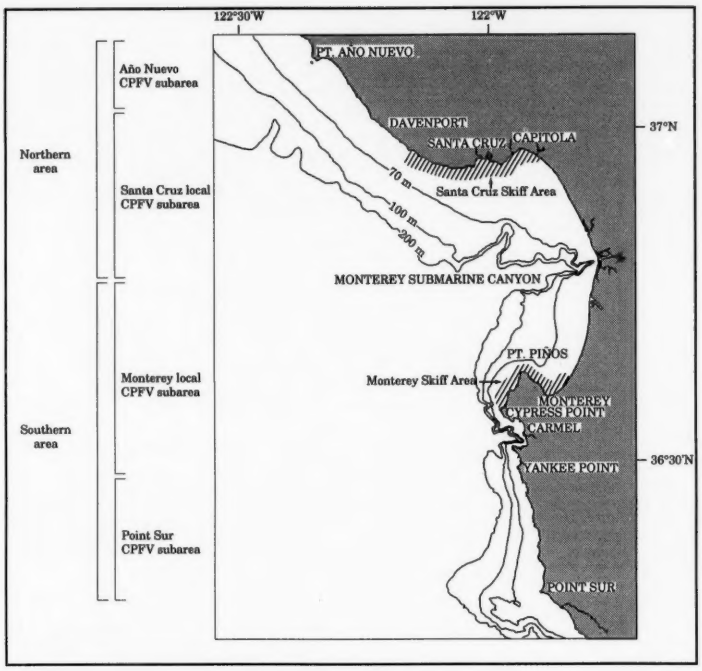

Figure 1. — Monterey Bay region showing fishing ports, CPFV areas and subareas, and skiff areas.

Several different programs have been conducted by the California Department of Fish and Game (CDFG) to survey the marine fishes caught in the recreational fisheries in the Monterey Bay region. Starting in 1947, CPFV logbooks provide information on the number of passengers fishing and the number of fish caught in the region, but do not indicate individual species of rockfish. Catch surveys from 1959 to 1972 and from 1977 to 1986 provide information on species composition and relative abundance. These catch surveys were combined to allow examination of interannual variability and long-term trends in the species composition.

Logbook Data

Information on fishing effort was available from summaries of CPFV logbooks submitted to the CDFG. Logbook data include the number of passengers and the number of fish caught per species group. Rockfishes were recorded as one group in the logbook. Unfortunately these logbooks are not completely accurate because not all trips are reported and catch is estimated by the skipper. Skippers reported 73% of the actual number of anglers and 71% of the fish caught on trips observed by the CDFG in the Monterey Bay region from 1987 to 1991 (Reilly et al.[2]). Logbook data are only available summarized by region; Santa Cruz and Monterey CPFV's are grouped as one region.

Table 1.—Total fish sampled for species composition by area for CPFV's and skiffs for each sampling program: (N) NCMSFS, Northern California Marine Sport Fish Survey; 1959-72; (C) CCRS, California Cooperative Rockfish Survey, 1977–86; (M) MRFSS, Marine Recreational Fish Statistics Survey, 1979–86. Blanks indicate no data available.

		Total fishes sampled in the Monterey Bay region									
		CPFV					Skiff				
Year	Survey	Total	Año Nuevo	Santa Cruz	Monterey	Point Sur	Total	Santa Cruz	Capitola	Monterey	Pacific Grove
1959	N	6,714		6,714			31,178	4,688	10,212	16,077	201
1960	N	44,804	7,498	16,817	20,489		1,674	978	197	499	
1961	N	18,281	5,252	5,850	7,179		3,894	1,645	1,186	1,063	
1962	N	15,009	3,707	5,199	6,103		9,725	3,553	3,121	3,051	
1963	N	21,049	3,788	5,255	12,006		14,914	3,374	4,027	6,796	717
1964	N	25,475	2,212	5,956	17,307		19,584	6,048	4,530	8,807	199
1965											
1966	N	9,524	872	2,061	6,591		11,326	4,260	2,491	4,247	328
1967	N	7,197	702	1,625	4,592	278	11,300	4,437		5,980	883
1968	N	7,312	492	1,721	4,516	583	15,458	3,587		10,266	1,605
1969	N	7,828	417	2,916	4,016	479	16,827	2,856		12,770	1,201
1970	N	8,202	823	1,784	4,816	779	20,063	3,962		16,101	
1971	N	7,696	353	1,171	5,736	436	10,670			10,670	
1972	N	3,849		750	3,099		8,386	1,750		6,636	
1973											
1974											
1975											
1976											
1977	C	7,863	340	1,547	4,635	1,341					
1978	C	1,873			1,453	420					
1979	C	1,425		31	1,159	235					
	M	984		43	941		1,388	728		660	
1980	C	1,431		32	1,332	67					
	M	3,002		34	2,968		1,591	982		609	
1981	C	1,365		93	1,194	78					
	M	955		44	911		584	244		340	
1982	C	868		158	695	15					
	M	2,688		362	2,326		1,288	730		558	
1983	C	1,373		207	1,139	27					
	M	3,251		622	2,629		2,193	1,032	6	1,155	
1984	C	614		86	498	30					
	M	4,877		946	3,931		4,844	1,803	1,503	1,538	
1985	C	609		29	537	43					
	M	7,609		1,653	5,956		4,865	1,986	1,523	1,356	
1986	C	68			68						
	M	6,866		1,968	4,898		3,371	1,590	1,035	746	
Totals		23,1701	26,754	66,382	133,754	4,811	195,123	50,233	29,831	109,925	5,134

Catch Surveys

Information on the species composition of the catch from CPFV's and skiffs was obtained from several surveys covering different time periods. The earliest survey began in 1959, and data from the latest survey were available through 1986. Although surveys were not conducted in a few years, compiling the data from these surveys provides species composition for 23 of the 28 years.

Species composition in recreational fisheries was determined by the CDFG from 1959 to 1972 under the Northern California Marine Sport Fish Survey (NCMSFS) and related surveys. Fish species were recorded throughout northern and central California from 1958 to 1961 (Miller and Gotshall, 1965) and from San Francisco to Yankee Point for 1962–64 and 1966. In other years, 1967–72, only the catch from skiffs and CPFV's from the Monterey Bay and Morro Bay areas was sampled for species composition (Miller and Geibel, 1973). Combining information from these surveys provides species composition data for skiffs from 1959 to 1972 and for CPFV's from the northern Monterey Bay area from 1959 to 1972 and the southern Monterey Bay area from 1960 to 1972, with the exception of 1965 when no samples were taken (Table 1).

No sampling of recreational fisheries was conducted in the Monterey Bay region from 1973 until 1977 when the California Cooperative Rockfish Survey (CCRS) was initiated by the CDFG and the National Marine Fisheries Service (NMFS) (Table 1). This survey collected information on species composition and length of rockfish and lingcod from the CPFV's operating out of Santa Cruz and Monterey. Species other than rockfish and lingcod were not consistently recorded in the CCRS survey, and therefore they were presumably under sampled.

Starting in 1979 the Marine Recreational Fishery Statistics Survey (MRFSS), funded by the NMFS, surveyed species and size of fish collected in all types of marine recreational fishing along the Pacific Coast (Holliday, 1984). Species composition from 1979 through 1986 for skiffs and CPFV's from the Santa Cruz and Monterey areas were used in this analysis.

Two surveys, CCRS and MRFSS, were conducted from 1979 to 1986. During this period the number of fish sampled by CCRS declined and the number sampled by MRFSS increased such that neither survey alone covered the whole period adequately (Table 1). Species composition estimated for rockfish from the two programs showed similar trends in relative abundance, allowing data from these two surveys to be combined for 1979 to 1986. Even after combining the two surveys, the number of fish sampled in the northern Monterey Bay area from 1978 to 1981 was less than 200 fish per year, and was insufficient for analysis of species composition (Table 1).

In 1977 and 1978 when only CCRS data were available, adjustment for the bias toward rockfish and lingcod in CCRS sampling was made. The mean proportion of nonrockfish (not including lingcod) from the combined surveys for available years was used as the proportion of nonrockfish for 1977 and 1978. For the northern Monterey Bay area from 1982 to 1986, nonrockfish averaged 6.7%, and for the southern Monterey Bay area from 1979 to 1986 nonrockfish averaged 10.0% of the number of fish caught. Rockfish and lingcod percentages were proportionally adjusted.

The database created from these different sampling programs includes species composition from CPFV's and skiffs, expressed always as a percentage of total numbers of fish retained. CPFV trips in the Monterey Bay region can be divided into two fishing areas for the whole time series: Northern (from Año Nuevo to the northern edge of the Monterey Submarine Canyon) and Southern (from the southern edge of the

Monterey Submarine Canyon to Point Sur). CPFV's travel up to 30 km from port at times to fish at Año Nuevo or Point Sur. Data from these distant fishing areas were distinguished from local areas in the earlier surveys, but not in later years. Therefore, whenever possible, four CPFV areas were considered, two near port (Santa Cruz and Monterey) and two distant areas (Año Nuevo and Point Sur). Because private and rental skiffs usually fish within 7 km of port, only the near port areas were available, i.e. Santa Cruz (including Capitola) and Monterey (including Pacific Grove).

Results

Effort

Logbook data indicate trends in effort in the CPFV fishery. Despite a decline in effort from 1960 to 1963, the number of anglers from ports in Monterey Bay doubled between 1960 and 1981 (Fig. 2a). There was a 50% reduction in fishing effort between 1981 and 1985 as the number of CPFV anglers temporarily dropped, but effort recovered by 1988.

Mean catch per angler day reported in logbooks has fluctuated between 8 and 13.5 fish (Fig. 2b), with rockfish ranging from 82% to 95% of the catch at 6.7 to 12.5 rockfish per day. The CPFV catch of all species declined from 11 to 8 fish per angler per day from 1960 to 1961. Logbook records include Pacific salmon fishing trips, and a higher proportion of effort was directed toward salmon from 1961 to 1962 and from 1985 to 1990, resulting in higher catches of salmon but lower catch per angler day of total fish since salmon anglers ususally catch only 1–2 fish per day. In 1971 the limit on total rockfish retained per day was reduced from 20 to 15 fish per angler, and there was a corresponding drop in catch per angler day that lasted 2 years. Catch per angler day increased between 1979 and 1983. High catch per angler day combined with high numbers of anglers to produce all-time record catches of over 500,000 fish per year from Monterey Bay CPFV's in 1981 and 1982.

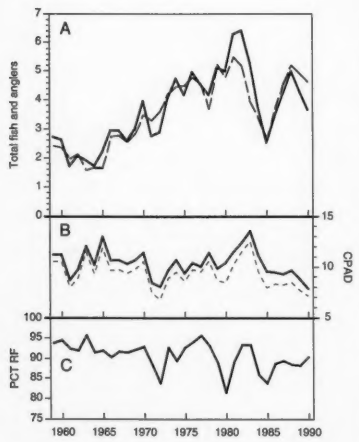

Figure 2. — Data from logbooks for Monterey Bay region. A = Total fish (× 100,000) line, total anglers (× 10,000) dashes. B = Total catch per angler day. C = Percent rockfish in catch.

The percentage of rockfish in the CPFV catch varied more during the period of the later surveys, from 1977 to 1986, than during the period from 1959 to 1972, and the mean percent of rockfish declined slightly from 91% in the earlier period to 89% in the later period (Fig. 2c). Declines in the proportion of rockfish in the CPFV catch reflect increases in the catch of nonrockfish species. In 1972 lingcod jumped to 14% of the reported catch. In 1980 lingcod, sablefish, *Anoplopoma fimbria*, and chub (Pacific) mackerel, *Scomber japonicus*, totaled 15% of the reported catch. In both 1984 and 1985 chub mackerel and Pacific whiting, *Merluccius productus*, together totaled 11% of the catch.

Skiff fishing has increased in relative importance throughout northern and central California (Karpov et al., 1995). Reports of skiff fishing effort for the Monterey Bay region were available only from NCMSFS from 1959 to 1961 (Miller and Gotshall, 1965), and MRFSS from 1981 to 1986 (Karpov et al., 1995). These two surveys sampled effort in different ways. NCMSFS surveyed effort at launch sites and skiff rental concessions on various weekdays and weekends during one year and expanded effort for the total year. MRFSS calculated effort from a telephone survey of residents in coastal counties; mean effort was calculated from 6 years of surveys (Holliday, 1984). In the Monterey Bay region, annual angler days for bottom fishing skiffs increased from 23,000 to 95,000 and average catch increased from 191,000 to 681,000 fish per year between the 1959–61 survey and the 1981–86 survey, a fourfold increase in anglers and in fish landed. Although these surveys differed in technique, they do indicate a general increase in the fishing effort and catch. This agrees with an estimated fourfold increase statewide for the same periods with adjusted data (Karpov et al., 1995), and with the 59% increase in skiff fishing effort observed from San Francisco to Yankee Point between 1959 and 1966 (Miller et al.[1]).

CPFV Species Composition

Combining data from all areas in the Monterey Bay region for all years surveyed, rockfish composed 90% of the fish caught by CPFV anglers. Up to 45 species of fish occur in the sampled catch per year. Species listed in Table 2 include all species ranking among the ten most abundant species in at least one of the six subareas (four CPFV or two skiff) listed in the table. Blue rockfish ranked first in abundance (34%) in the combined Monterey Bay region, followed by yellowtail rockfish (20%), and chilipepper (6%). Other rockfish species each contributed less than 5% to the catch. Lingcod were the most important nonrockfish species.

Different species are important in the CPFV catch from the northern and southern halves of the Monterey Bay region. In the northern area, yellowtail rockfish (25%) is the most abundant species followed by blue rockfish (20%), whereas in the southern area, blue rockfish (33%) are more abundant than yellowtail rockfish (15%). Canary rockfish, *S. pinniger*; copper rockfish, *S. caurinus*; greenstriped rockfish, *S. elongatus*; and greenspotted rockfish are important in the northern area, whereas olive, widow, and rosy rockfish are also important in the southern area. Chilipepper, bocaccio, and lingcod are important in both areas.

Two subareas were distinguished in the northern CPFV fishing area from

1960 to 1977, the distant fishing area around Point Año Nuevo and the local Santa Cruz area which included all areas from Davenport to the northern edge of the Monterey Submarine Canyon. The composition of the catch from the Año Nuevo subarea, available for 1960–71 and 1977, is dominated by blue rockfish (49%), lingcod, copper rockfish, and black rockfish (Table 2) and is quite different from the composition from any other area. The catch for the same years from the local Santa Cruz subarea has a comparatively low percentage of blue rockfish (10%) and relatively high percentages of yellowtail rockfish (37%), chilipepper, and greenspotted rockfish. Canary rockfish were important in both subareas.

Two subareas were distinguished in the southern CPFV fishing area. The distant subarea, Point Sur, included fishing areas from Yankee Point south to Point Sur, and the local Monterey subarea extended from the Monterey Submarine Canyon south to Yankee Point. Data from the Point Sur subarea are available for 1967–71 and 1977–79 but comprise only 2% of the total sampled fish. The Point Sur subarea has a higher percentage of chilipepper, widow rockfish, olive rockfish, and yellowtail rockfish, and a lower percentage of blue rockfish than the local Monterey catch for the same years.

CPFV Inter-year Variations

CPFV's fish primarily over rocky outcroppings where they catch not just one but a number of species, and the species composition changes with the depth fished. Some rockfish species such as blue, black, and olive rockfish are most commonly caught from midwater aggregations consisting of one or more species in water <70 m. Other rockfish species, such as black-and-yellow, *S. chrysomelas*; gopher, kelp, brown, and grass rockfish, *S. rastrelliger*, dwell on or near the rocky bottom, usually at depths <50 m (Miller and Geibel, 1973; Eschmeyer et al., 1983; Hallacher and Roberts, 1985). Fish of both the midwater and bottom-dwelling groups may be caught simultaneously by anglers on a boat. Yellowtail rockfish are another midwater schooling variety of rockfish, but they are generally caught over outcroppings 70–100 m deep in this region. Deeper water species caught near the bottom on rocky outcroppings, sand, or mud at 70–200 m include bocaccio, chilipepper, greenspotted rockfish, and greenstriped rockfish (Heimann, 1963; Miller and Lea, 1972; Eschmeyer et al., 1983; Love et al., 1990).

Groupings by depth category were used for graphic presentation of the species composition by year. Shallow water blue rockfish and deep water yellowtail rockfish, the most abundant species in most areas, are displayed individually. Species occurring in similar depth ranges are grouped together for analysis of trends. Other than blue rockfish, the seven most important rockfish caught at <70 m depth in either the CPFV or skiff fishery (black, brown, gopher, kelp, black-and- yellow, grass, and olive rockfish) are grouped together as shallow water rockfish. The four principal deep water red rockfish species (greenspotted rockfish, greenstriped rockfish, chilipepper, and bocaccio) commonly caught at >70 m depth are grouped together.

Some species of rockfish do not fit these depth categories and are grouped together in the "other rockfish" category. This group includes canary, copper, and vermilion rockfish, *S. miniatus*, which occur in shallow water as young fish and in deeper water as larger adults (Eschmeyer et al., 1983; Love, 1991). It also includes widow rockfish which

Table 2.—CPFV species composition for total Monterey Bay Region, northern and southern areas, and four CPFV subareas: Año Nuevo (Año), local Santa Cruz (S.C.), local Monterey (Mon.), and Pt. Sur (Sur). Skiff species composition for total Monterey Bay region and for two skiff areas: Santa Cruz (S.C.) and Monterey (Mon.). Time periods differ due to lack of subarea resolution in some years. The 17 most abundant rockfish species are grouped with shallow-water species near the top, followed by indeterminate depth, and deeper-water species, and the five most abundant nonrockfish species last.

	CPFV							Skiff		
	CPFV areas[1]			CPFV subareas				Skiff areas[2]		
	Comb.	North	South	Año[3]	S.C.[3]	Mon.[4]	Sur[4]	Comb.	S.C.	Mon.
Rockfishes										
Blue, *Sebastes mystinus*	33.6	20.1	32.6	49.3	9.9	36.3	23.1	19.2	14.2	22.7
Olive, *Sebastes serranoides*	4.5	.4	7.5	1.0	.2	4.9	9.6	2.8	1.0	4.1
Brown, *Sebastes auriculatus*	.6	2.2	.1	3.4	1.5	.2	.0	2.9	6.4	.5
Gopher, *Sebastes carnatus*	.8	1.0	.4	3.0	.3	.3	.5	3.2	3.3	3.1
Black, *Sebastes melanops*	1.2	2.0	.1	6.0	1.1	.1	.1	1.8	3.0	1.0
China, *Sebastes nebulosus*	.4	.5	.2	1.8	.0	.1	.1	.3	.2	.3
Copper, *Sebastes caurinus*	1.4	3.5	.6	6.8	1.5	.6	.6	3.3	2.4	4.0
Starry, *Sebastes constellatus*	1.3	1.2	2.0	.0	1.4	2.2	1.8	.7	.1	1.2
Vermilion, *Sebastes miniatus*	.7	1.0	.6	1.3	.9	.5	1.9	.8	.1	.7
Canary, *Sebastes pinniger*	3.3	5.7	2.0	5.4	6.0	2.1	1.7	2.7	3.8	2.0
Rosy, *Sebastes rosaceus*	3.4	1.9	4.3	.8	2.1	4.8	2.2	2.9	1.3	4.1
Widow, *Sebastes entomelas*	4.7	1.8	5.6	.3	2.1	6.3	10.5	.3	.5	.1
Yellowtail, *Sebastes flavidus*	19.4	25.1	14.9	5.4	36.7	14.7	16.1	3.0	2.7	3.2
Greenspotted, *Sebastes chlorostictus*	2.3	6.1	1.3	.2	6.3	2.2	2.5	.3	.4	.3
Greenstriped, *Sebastes elongatus*	1.1	3.1	1.1	.0	2.7	2.1	1.5	.1	.1	.0
Chilipepper, *Sebastes goodei*	5.7	7.5	7.4	.0	10.7	5.2	14.0	.2	.1	.3
Bocaccio, *Sebastes paucispinis*	4.5	3.6	7.2	.3	4.8	7.7	7.3	.7	.5	.9
Other rockfishes	1.4	2.7	1.7	.4	1.5	1.9	3.1	5.9	8.6	7.0
Total % Rockfish	90.3	89.4	89.3	85.4	89.7	92.2	96.6	51.1	44.7	55.5
Nonrockfishes										
Sablefish, *Anoplopoma fimbria*	1.4	2.7	1.3	1.1	4.3	.4	.5	.4	.3	.5
Jacksmelt, *Atherinopsis californiensis*	.0	.0	.0	.0	.1	.1	.0	1.8	2.8	1.1
Pacific sanddab, *Citharichthys sordidus*	1.1	1.2	1.1	.0	1.5	1.5	.4	20.2	4.9	30.9
White croaker, *Genyonemus lineatus*	.4	.5	.4	.1	.7	.3	.0	16.0	37.3	1.3
Chub mackerel, *Scomber japonicus*	.8	.5	1.2	.0	.0	.0	.0	3.1	2.9	3.2
Lingcod, *Ophiodon elongatus*	4.2	3.7	3.6	11.6	2.0	3.8	2.2	3.3	3.1	3.4
Other	1.8	2.0	2.8	1.8	1.7	1.7	.3	4.1	4.0	4.1
Total % nonrockfishes	9.7	10.6	10.4	14.6	10.3	7.8	3.4	48.9	55.3	44.5

[1] 1960–72, 1977–86.
[2] 1959–1972, 1979–1986.
[3] 1960–71, 1977.
[4] 1967–71, 1977–79.

occur in deep midwater aggregations and are not commonly associated with deep water red rockfish. Rosy rockfish, classed with the deeper than 70 m group by Miller and Geibel (1973) but as most common at 30–46 m by Eschmeyer et al. (1983), are also placed in this category. Fish identified as rosy rockfish prior to 1972 may have included two species similar in appearance found only in deep water: rosethorn rockfish, *S. helvomaculatus* (119–549 m); and swordspine rockfish, *S. ensifer* (70–143 m) which may have extended the depth range (Eschmeyer et al., 1983). These three species are also small and therefore are often thrown back. Species occurring infrequently (<2%) and not listed in the shallow or deep water categories are also included in the "other rockfish" category.

Within each area there are differences over time in the relative importance of particular species. In the northern half of the Monterey Bay region, blue rockfish (Fig. 3a, top) comprised over half of the CPFV catch in 1959 but declined between 1960 and 1969 . It partially recovered in 1970–72, but was relatively low when sampling resumed in 1977 and extremely low from 1982 to 1986. Yellowtail rockfish was the leading species during most of the 1960's and from 1982 to 1983, but it declined in the catch from 1984 to 1986. The deep water red rockfish group's importance was sporadic at first but became increasingly important from 1983 to 1986.

The northern area is divided into two subareas. Boats fishing the distant Año Nuevo subarea caught lingcod and a variety of shallow water rockfish, especially blue rockfish, which dominated the catch from 1960 to 1971 (Fig. 3b). Within that period there was a gradual decline in the proportion of blue rockfish from 1960 to 1968 and a sharp increase in 1969. Lingcod ranked second in the proportion of fish caught in most years with highest catches in 1967 and 1968. The shallow water rockfish group was important in this area, especially in years with reduced catches of blue rockfish; it includes gopher rockfish and black rockfish which were important through 1968, and brown rockfish which was 20% of the catch in 1977. Canary rockfish and copper rockfish from the "other rockfish" category were both consistent components of the Año Nuevo catch, reaching highest proportions when blue rockfish were scarce. The deeper species were a minor proportion of the catch; yellowtail rockfish comprised less than 11% per year, and deep water red rockfishes were rare in the catch from this area.

Species composition data from northern area commercial passenger fishing trips that did not go to Año Nuevo were grouped together as the local Santa Cruz subarea (Fig. 3c). Yellowtail rockfish dominated the catch in all years except for 1964, 1970, and 1977. In 1964 chilipepper (deep water red rockfish) dominated the catch; in 1970 blue and "other rockfish" (mostly canary rockfish) contributed more than yellowtail rockfish to the catch, and in 1977 both the deep water red group and the shallow water blue rockfish ranked higher than yellowtail rockfish in the catch. Catches of deep water red rockfishes fluctuated widely and varied in dominant species, chilipepper dominated in 1962, 1964, and 1977 (19%, 53%, and 31%, respectively), bocaccio in 1966 (15%), and greenspotted rockfish in 1963 and in 1969 (11% and 10%, respectively) .

In the southern half of the Monterey Bay region, CPFV's caught a higher proportion of blue rockfish than in the local Santa Cruz area. Blue rockfish were the most abundant species and yellowtail rockfish were second in abundance from 1960 to 1971 except in 1961 and 1962 when yellowtail rockfish dominated (Fig. 4a). Blue rockfish declined in the catch in 1972. When sampling resumed in 1977, the southern area catch had a relatively high proportion of deep water species. Bocaccio was the most important deep water red species through 1972, but chilipepper dominated the deep water red group in 1977, 1978, 1984, and 1985. Deep water species peaked in 1978 and then declined through 1980 as blue rockfish reappeared in the catch. Blue rockfish did not remain the leading species for long, and as they declined, the deep water species, especially chilipepper, increased through 1986. Increased catches of sablefish from 1978 to 1980 and Pacific whiting from 1984 to 1986 reflect the deeper waters fished.

The distant-water fishery to the Point Sur subarea began after large blue rockfish were discovered in the area by CDFG exploratory fishing in 1962. In the late 1960's the leading species caught in the Point Sur subarea fluctuated between blue and yellowtail rockfish (Fig. 4b). The species composition was similar to the catch from the entire southern area, but with higher percentages of olive rockfish from the shallow water group (through 1971) and widow rockfish from the "other rockfish" group in 1969 (49%). The catch shifted to deep water species by the 1977–79 period, and chilipepper became the leading species. This shift was even more pronounced at Point Sur than in the rest of the southern area. After 1979, fishing locations were not usually recorded and not enough fish were sampled for analysis (< 100 per year) from the Point Sur subarea (Table 1).

Skiff Species Composition

The species composition of the skiff catch differs from the CPFV catch in the proportion of nonrockfish species. Nonrockfish species were a significant component of the skiff catch from the whole Monterey Bay region for all years sampled comprising 43% of the catch (Table 2). Blue rockfish was the leading species from the combined areas, but was closely followed by Pacific sanddab, *Citharichthys sordidus*; and white croaker.

Examining the skiff catch by area, differences exist in the Santa Cruz and Monterey species compositions. In Santa Cruz, white croakers were the most abundant species (38%), followed by blue rockfish. Brown rockfish, black rockfish, and jacksmelt, *Atherionopsis californiensis*, were more important in Santa Cruz than in Monterey. Pacific sanddab comprised only 5% of the catch in Santa Cruz.

In the Monterey skiff catch, Pacific sanddab was the most abundant species at 30% of the catch. Blue rockfish was second in abundance in Monterey as in Santa Cruz. Olive, copper, and rosy rockfish were more important in the skiff catch from Monterey than from Santa Cruz. Canary, gopher, and yellow-

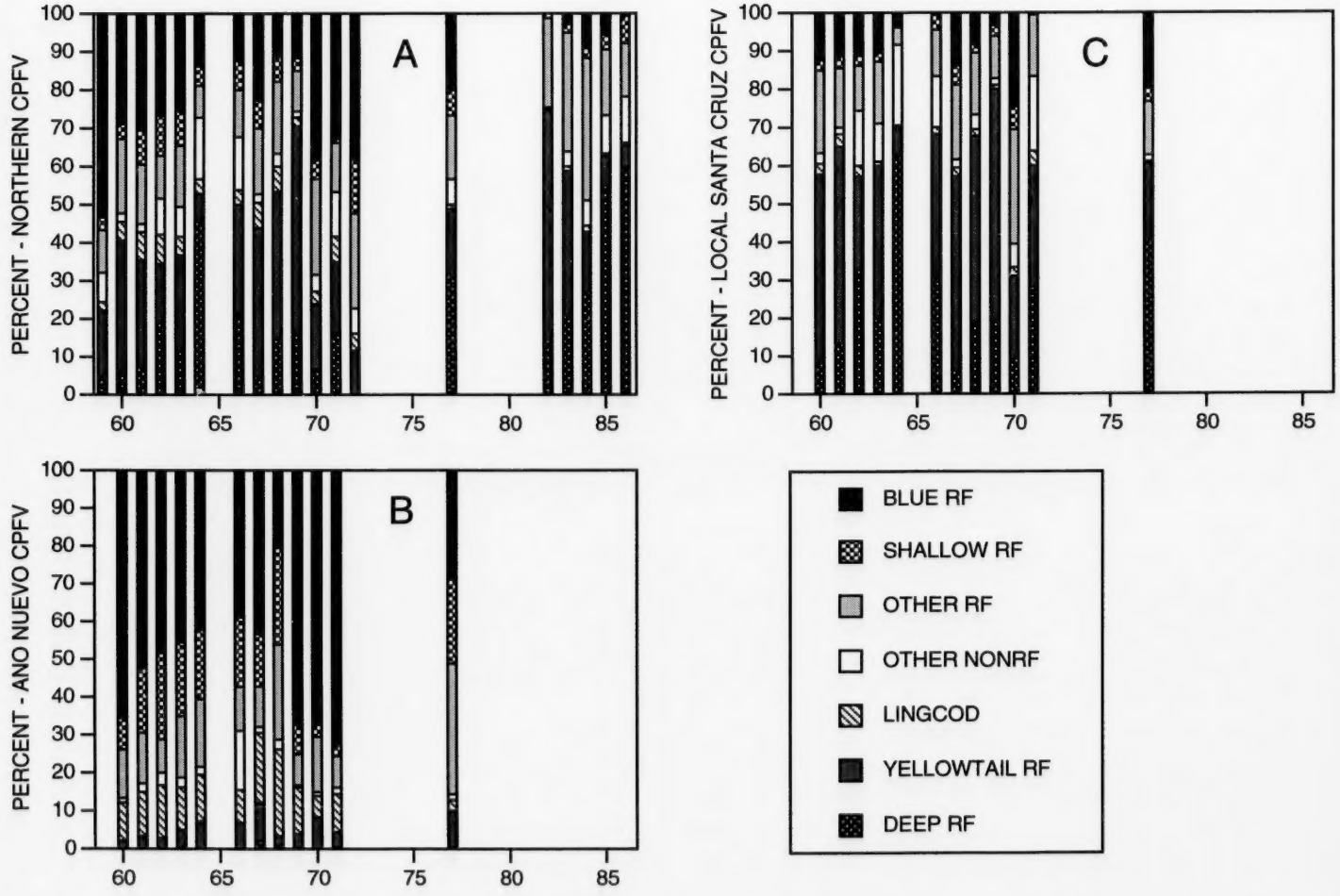

Figure 3. — CPFV species composition in cumulative percentages: A = entire northern area, B = Año Nuevo subarea, C = local Santa Cruz subarea. Vertical orientation of species groups is related to depth stratification, see text for definition of species groups.

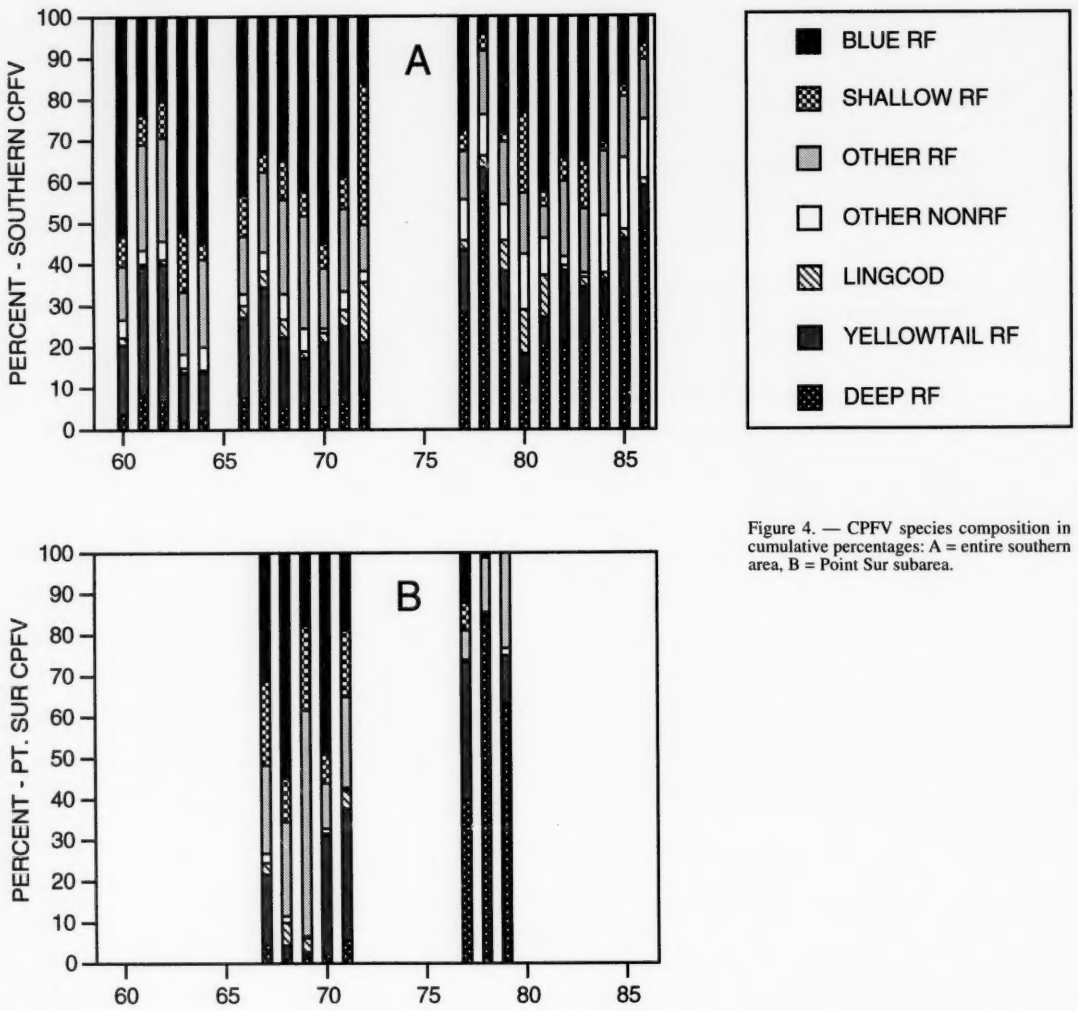

Figure 4. — CPFV species composition in cumulative percentages: A = entire southern area, B = Point Sur subarea.

tail rockfish, lingcod, and chub (Pacific) mackerel each comprised 2–3% at both locations. White croaker, the most abundant species in Santa Cruz, comprised < 2% of the Monterey catch. Although lingcod did not provide a particularly high percentage of the catch by numbers, their relatively large size made them an important component of the catch in both areas.

Skiff Inter-year Variations

Examining variations between years among nonrockfish species from the Santa Cruz skiff catch (Fig. 5a), white croaker was the leading species in all years sampled except 1970, 1982, and 1983. Lingcod provided a fairly constant proportion of the catch through 1982, after which it declined. Other nonrockfish species (grouped together in Fig. 5a) were present in smaller amounts in the catch, some for only a few years. Pacific sanddab comprised less than 10% of the catch except in 1980. Chub (Pacific) mackerel appeared as a significant part of the skiff catch (9–22%) only from 1982 to 1984, as its population expanded after 20 years of scarcity throughout California (MacCall et al., 1985). Jacksmelt was important only in the early years from 1959 to 1968, comprising 6% of the catch for that period and 0.3% thereafter.

Blue rockfish was the most frequently landed rockfish species for Santa Cruz skiffs, comprising from 7 to 26% of the catch (Fig. 5a). Increases in the relative abundance of blue rockfish in the Santa Cruz skiff fishery occurred from 1967 to 1970 and from 1981 to 1982. Yellowtail rockfish con-

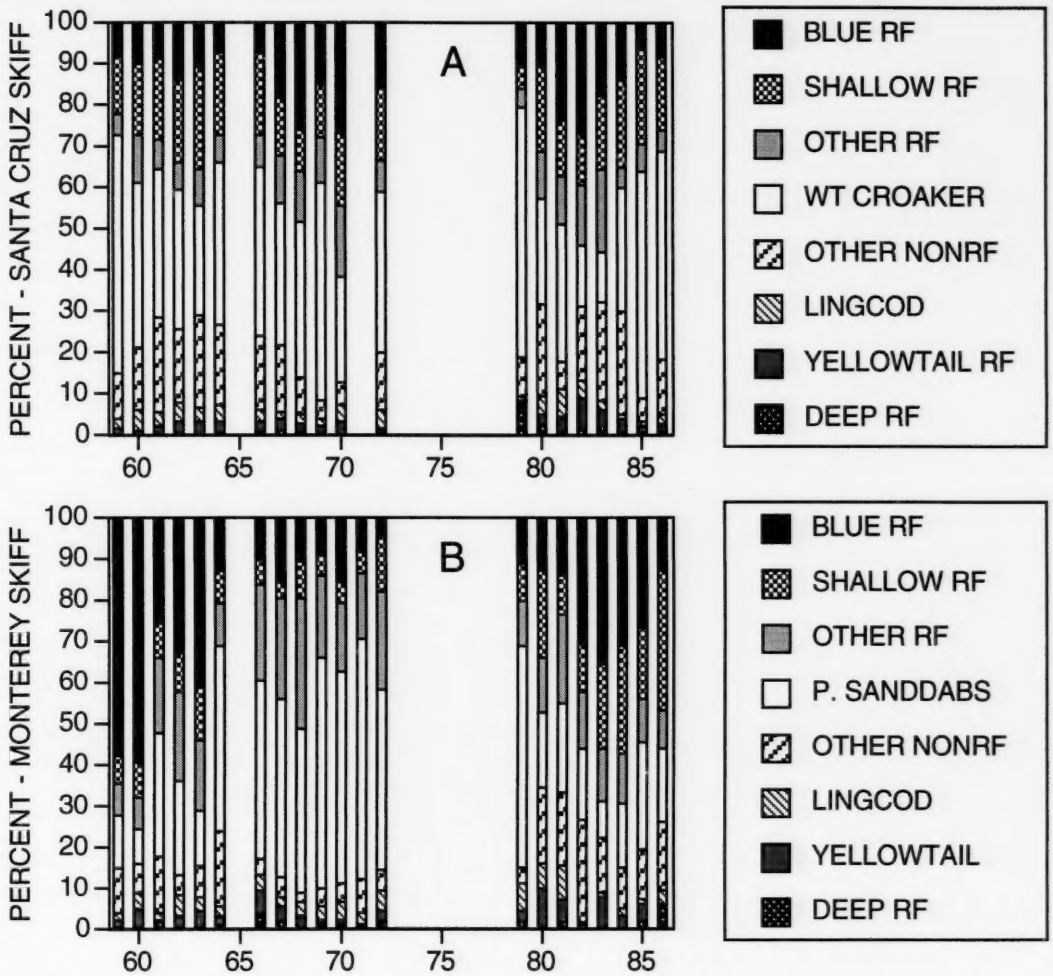

Figure 5. — Skiff species composition in cumulative percentages: A = Santa Cruz, B = Monterey.

tributed no more than 6% (1982), and the highest contribution of the deep water red rockfish group (7%) came in 1979 from young bocaccio which were caught in shallow water near shore before they migrated to deeper water. The shallow water rockfish group was important in the skiff catch in all years, declining in proportion of the catch when blue rockfish were abundant, but the relative contribution of individual species varied as displayed in Figure 6a. Brown rockfish increased in abundance from 1960 to 1966 and remained important through 1986. Grass rockfish, the most shallow dwelling species, was important from 1959 to 1964 but had practically disappeared by 1967. Bottom dwelling gopher and black-and-yellow rockfish reached their highest contributions to the catch when midwater blue rockfish catches were low.

Nonrockfish species were also important in the Monterey skiff catch. Pacific sanddab was either the most abundant or second most abundant species in all years except 1982 and 1983 (Fig. 5b). Sanddab was a preferred species between 1966 and 1972, and it may have diverted some effort away from rockfish (Miller and Geibel, 1973). Chub (Pacific) mackerel became the leading species for one year with 22% of the catch in 1981, and it was second with 19% in 1982. It was also caught by CPFV's in this area in 1981, a year ahead of its increase in the Santa Cruz skiff catch. Lingcod catches were highest from 1979 to 1981.

Blue rockfish alternated with Pacific sanddab as the most abundant species in all years except 1972 when blue rockfish hit its lowest level in the Monterey skiff catch (Fig. 5b). Blue rockfish, dominant through 1963 (except for 1961), dropped in abundance in 1964 and did not reclaim its position as the

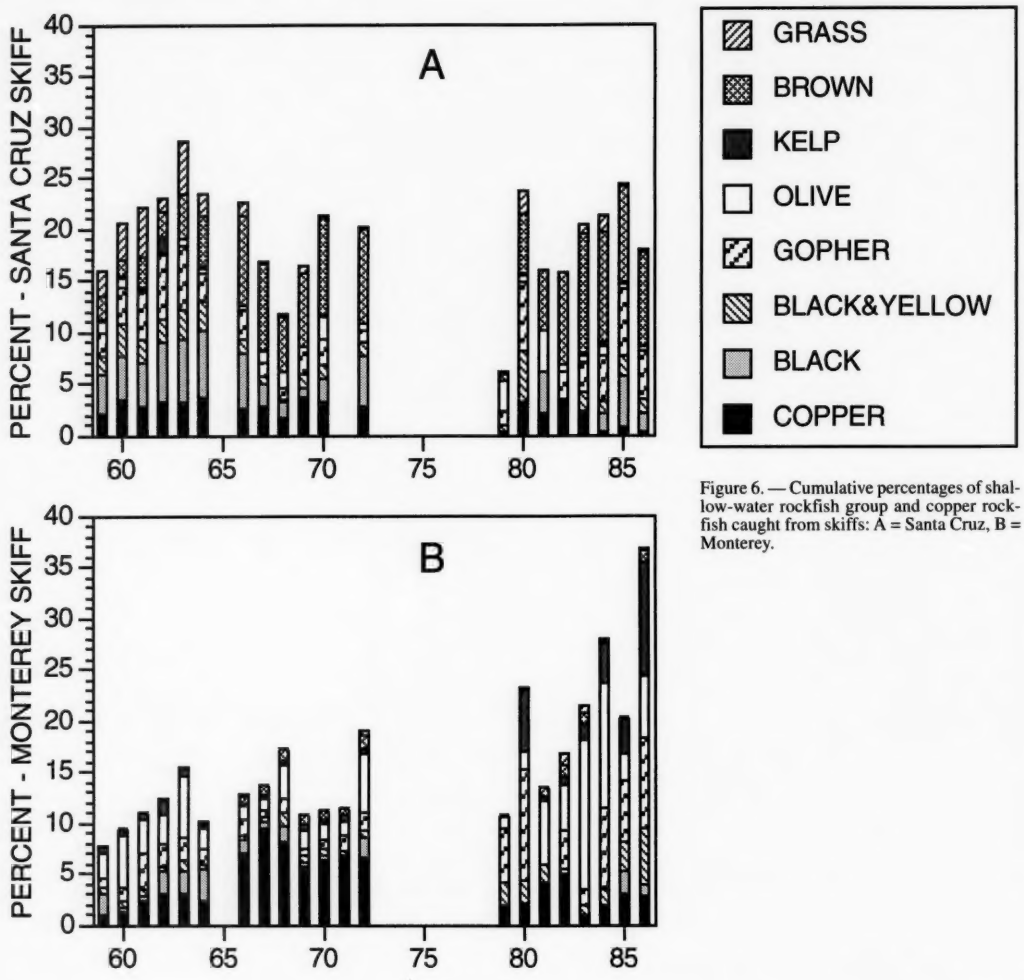

Figure 6. — Cumulative percentages of shallow-water rockfish group and copper rockfish caught from skiffs: A = Santa Cruz, B = Monterey.

leading species until 1982–85, 1 year later than in the Monterey CPFV and Santa Cruz skiff catches. Yellowtail rockfish catches were generally low but peaked before and during the recovery of blue rockfish. The deep water group of species is rare in the Monterey skiff catch; highest catches were 4% in 1966 (mostly bocaccio) and 5% in 1986 (mostly chilipepper). Shallow- water rockfish became increasingly important in the 1980's as the Pacific sanddab decreased. Olive rockfish, frequently caught in midwater with blue rockfish in this area, reached its highest proportion in the catch during the blue rockfish recovery in 1983 and 1984 (Fig. 6b). Kelp, gopher, and black- and-yellow rockfish all increased in relative abundance before and after the increase in blue rockfish. Copper rockfish was at its highest proportion in the catch from 1966 to 1972, the period of high Pacific sanddab catches.

Discussion

The waters of the Monterey Bay region have been fished by both recreational and commercial fishermen for more than a century. As in many regions, fishing pressures were heaviest near port in the early years, and expanded first along the shore and then to deeper waters as fishermen became more mobile and fishing technology developed (Reiger and Loftus, 1972). The nearshore zone of the Monterey region has been subject to longline fishing for rockfish since 1875 (Phillips, 1964). Longline rockfish catches in central California declined between 1935 and 1942, but averaged 2 million pounds per year (Bureau of Marine Fisheries, 1949). Development of new technology such as otter trawls has led to increased catches from deeper waters since the 1950's (Heimann, 1963), and gillnet fishing has contributed to the

catch in recent years. Commercial catches averaged 3 million pounds in the 1960's and over 4 million pounds in the 1970's in the Monterey region (from CDFG annual catch bulletins). Fishing pressure, both recreational and commercial, affected rockfish survival and species composition long before the recreational fishing surveys used in this study were conducted, making it impossible to define the pre-exploitation species composition.

As in many heavily fished areas, larger species and older individuals have been heavily targeted for harvest first (Reiger and Loftus, 1972; Deimling and Liss, 1994). Recreational catches monitored in southern California showed shifts over time from emphasis on relatively large species such as tunas, *Thunnus* spp.; giant sea bass, *Stereolepis gigas*; white seabass, *Atractoscion noblis*; and California halibut, *Paralichthys californicus*; to smaller varieties including rockfish (Young, 1969; Skull et al., 1987). In the Monterey area, Pacific salmon was important in both the commercial and recreational fisheries through the 1920's, but it became a depleted and undependable resource in this area by 1930 (Bureau of Marine Fisheries, 1949), at which time rockfish became the mainstay of the CPFV fishery (Young, 1969). As larger species, higher on the food chain, become depleted from heavy exploitation, fisheries generally diversify to include more varieties of fish and fish of lower trophic levels (Deimling and Liss, 1994).

Several of the life history characteristics of rockfish (residential behavior, variable year-class strength, and longevity) contribute to high vulnerability to localized overfishing. Residential behavior reduces the potential for restocking a depleted area through immigration of adult fish.

Most of the species of rockfish studied are primarily residential as adults. The degree of movement does vary between different species with shallow water benthic species having the greatest site fidelity, whereas deeper nonbenthic aggregating species are more likely to undergo movements, especially ontogenetic movements from shallow to deeper water at some point in their development (Love et al., 1991). Tagging studies indicate that movements of more than 3 km were rare for adult shallow water benthic species including gopher and black-and-yellow rockfish (Larson, 1980) and brown rockfish and slightly deeper copper rockfish (Hartmann, 1987; Matthews, 1990). For shallow water nonbenthic blue (Miller and Geibel, 1973) and olive rockfish (Hartmann, 1987), 85% moved <1.6 km, and only 2% moved >10 km. Among three nonbenthic species (bocaccio, yellowtail, and black rockfish) which reside in shallow water as juveniles and deeper water as adults, some adults exhibit more extensive movements. Up to 30% of mature yellowtail rockfish moved >25 km (Stanley et al., 1994), although some yellowtail rockfish exhibited residential behavior and even returned to their home sites when removed as far as 22 km (Carlson and Haight, 1972). For both black rockfish (Culver, 1987) and immature bocaccio, 30% moved more than 16 km, although all mature bocaccio recaptured were still at the site of tagging up to two years later (Hartmann, 1987). The great diversity of rockfish behavior makes it difficult to generalize for all species, but rockfish do not have extensive seasonal migrations, and some species, especially deep water species, have some individuals that move several kilometers, while many rockfish, especially shallow water benthic species, remain in the same area where they settled as juveniles.

The higher degree of site fidelity observed in residential shallow water species may make these rockfish particularly susceptible to overexploitation. Increased vulnerability to overfishing due to residential behavior was observed in olive rockfish on heavily fished rocky outcroppings (Love, 1980), and in a comparison of two similar artificial rock piles in Monterey Bay, one marked for recreational fishing and one unmarked. The recreationally fished location had a reduced total catch per angler hour (Solonsky, 1983). Although limited recruitment of adult and subadult fish to the exploited area continued, the recruitment of large fish did not equal the harvest, and the average size of rockfish at the exploited location declined as older fish were continuously removed (Matthews, 1985). Blue rockfish populations depend on growth of young fish recruited as juveniles to the localized area rather than immigration of large numbers of adults from distant areas, and they are vulnerable to overexploitation if annual recruitment does not equal fish removed.

Also contributing to the risk of overexploitation is the high variability of year-class strength in many species of rockfish including Pacific ocean perch, *Sebastes alutus*; chilipepper, and widow rockfish (Norton, 1987; Hollowed and Wooster, 1992). Environmental conditions such as the warm water temperatures and decreased equatorward flow characteristic of El Niño events in central California may produce years of poor recruitment for many species (Ralston[3]). Sea surface temperatures that are either unusually cold or warm at the time of spawning indicate environmental conditions that negatively impact survival of larvae of blue and yellowtail rockfish (Ralston and Howard, 1995). In southern California, young stripetail rockfish, *S. saxicola*, was more abundant in cooler years, whereas a more southerly distributed species, calico rockfish, *S. dalli*, was more abundant in warmer years (Mearns et al., 1980). Although the response to environmental conditions is not the same for all species, inter-year variability in recruitment is characteristic of rockfish species.

A prolonged reproductive phase may be crucial to the survival of rockfish populations in the face of intermittent recruitment failures (Leaman and Beamish, 1984). Rockfish species are generally long lived with maximum ages of greater than 30 years for 20 out of 28 species reviewed (Love et al., 1990). Yellowtail, widow, and canary rockfish all may live for 60 years or more (Leaman and Beamish, 1984) and reach reproductive maturity at 5–9 years of age (Wyllie Echeverria, 1987), giving most species a potential reproduc-

[3] Ralston, S. (Editor). 1993. Progress in rockfish recruitment studies. U.S. Dep. Commer., NOAA, NMFS Southwest Fish. Sci. Cent., Tiburon Lab., Admin. Rep. T-93-01, 42 p.

tive life span of more than 20 years. However exploitation tends to decrease the number of age classes in a population, and when this occurs in species with highly variable recruitment success, it increases the risk of reproductive failure (Murphy, 1968). This leaves residential long-lived species with infrequent recruitment success vulnerable to recruitment overfishing near port.

Recreational Fishery Development

Blue rockfish experienced heavy exploitation near port in both Santa Cruz and Monterey as they became the focus of the recreational fishery in the late 1950's. Blue rockfish comprised an estimated 70–80% of the CPFV catch from the northern area according to skippers interviewed during the development of the catch survey by Miller (Miller and Geibel, 1973), and most of those fish were caught within 10 km of Santa Cruz. The high percentage of blue rockfish and other shallow water species implies a species composition near Santa Cruz similar to Año Nuevo's for this period rather than the deeper water species characteristic of the local Santa Cruz subarea in the 1960's.

Several changes in fishing techniques during the late 1950's may have contributed to heavy fishing pressure on blue rockfish. Fishing effort that had been directed toward salmon trolling was redirected to bottom fishing after 1956 as the relatively high salmon catches during 1953–56 declined (Miller and Geibel, 1973). The multiple-hook rig for rockfish, first used in 1957 in Monterey Bay (Smith, 1979), was particularly well suited to catching schooling pelagic rockfish such as blue and yellowtail rockfish. Earlier fishing techniques using single hooks baited with sardines or squid may have been more effective for catching larger, solitary fish which had become scarce. Sensitive fathometers became widely used about this time and may have aided skippers in locating schools of pelagic rockfish (Smith, 1979).

Blue rockfish populations were subjected to heavy fishing pressure not only from CPFV's but also from skiff anglers in the late 1950's and the 1960's. The percentage of blue rockfish dropped in 1960 for the local Santa Cruz CPFV catch and in 1961 for both the Monterey CPFV and skiff catches. About 33–50% of the blue rockfish caught in the local Santa Cruz area during 1960–64 were caught by skiff anglers (Miller et al.[1]). In the Monterey area, catches of blue rockfish increased in 1963 for both skiffs and CPFV's, but in Santa Cruz the catches remained low.

Area and Depth Fished

Santa Cruz CPFV skippers developed two alternative ways to provide adequate catches in the period of blue rockfish scarcity. The first alternative was to travel farther from port to find blue rockfish, and CPFV's traveled about 35 km from Santa Cruz to fish on rocky outcrops around Año Nuevo where they found numerous schools of large blue rockfish in the early 1960's (Fig. 3b). One- fourth of the CPFV fishing effort for the northern area was directed to Año Nuevo from 1961 to 1964, and over half the CPFV caught blue rockfish in the northern area came from Año Nuevo (Miller et al.[1]).

The second alternative to fishing for blue rockfish near Santa Cruz was to locate areas near port where other species were available. Schools of yellowtail rockfish were found on deep banks off Davenport at 65–100 m. Deep banks provided most of the local Santa Cruz catch during the 1960's (Miller and Geibel, 1973). The shift from yellowtail rockfish to deep water red species by 1984 (Fig. 4c) reflects another relocation to still deeper fishing areas including the edge of the Monterey submarine canyon. Santa Cruz skiffs, traveling limited distances from port, continued to catch shallow water rockfish. Yellowtail and deep water red rockfish species increased in the skiff catch only slightly, indicating a shift in fishing locations by the CPFV's rather than increased abundance of deep water species near shore.

When localized reductions of blue rockfish occurred in the Monterey skiff fishery in 1964, the CPFV fishery maintained high catches of that species by changing to slightly more distant fishing areas around the Monterey Peninsula and as far south as Yankee Point (Miller et al.[1]), but by 1967 they were taking occasional trips south to Point Sur. The species composition of the distant Point Sur area was similar to the local Monterey area, but the availability of larger fish made the longer trip worthwhile (Miller and Geibel, 1973). The southern area CPFV's were not as dependent on distant-water fishing through 1972 as the northern area CPFV's because of the extensive rocky bottom fishing areas around the Monterey Peninsula. However, by 1977 there was a shift to fishing for deeper species at the edge of the Monterey Submarine Canyon at 100 m and occasionally 200 m depths.

CPFV's have continued to fish primarily in deep water in recent years. In a CDFG survey during 1987–91, 61% of the observed CPFV trips in the entire Monterey Bay region fished in water deeper than 40 m, 20% fished shallower than 40 m, and the remainder fished both shallow and deep locations in the same trip (Reilly et al.[2]). The four deep water red rockfish species averaged 42% of the catch, yellowtail rockfish 8%, and blue rockfish 15% from the whole Monterey Bay region, very similar to the 1985–86 species composition.

Over time, fishing more distant waters appears to have been largely replaced by fishing nearer but deeper waters. The previously unexploited populations of large individuals at shallow fishing grounds within a day's travel from port were exhausted after a few years, and rockfish from distant areas are now the same mean size as rockfish from local areas in the Monterey Bay region (Reilly et al.[2]). The increased fuel prices in the 1980's have made distant fishing trips more expensive, and during 1987–91, 75% of the fish were caught less than 18 km from port (Reilly et al.[2]). Some trips are still made to more distant areas in search of particular species, but most of the fishing is conducted closer to port in deeper water.

Variations in Recruitment

Year-class strength can vary over both time and area. Midwater trawl surveys in northern California have docu-

mented inter-year variations in larval rockfish abundance. The relatively strong year classes of blue and of yellowtail rockfish found in the trawls were confirmed by diving surveys of first-year juvenile recruitment to nearshore kelp beds at two sites 100 km apart in Sonoma and Mendocino counties (Ralston and Howard, 1995). The same relatively strong year classes (1985, 1987, and 1988) were observed in a study of first-year juvenile recruitment of blue rockfish to kelp beds near Monterey (VenTresca et al.[4]). Thus, relatively strong year-classes of blue rockfish can extend over large sections of the coast. In some years, however, recruitment for a particular species is spatially limited. During one year of the recruitment to kelp beds studies (1991), moderate recruitment of blue rockfish occurred at Monterey and Sonoma counties but did not occur farther north at Mendocino county (VenTresca et al.[4]; Adams[5]). Whereas in 1993 blue rockfish recruitment was relatively strong at Mendocino county, it was weak at both Sonoma county (Eldridge[6]) and Monterey (VenTresca et al.[4]). Variation in patterns of coastal currents, eddies, upwelling plumes, and jets can all affect the distribution of rockfish during the pelagic larval and juvenile stages, leading to the patchy distribution observed in CalCOFI surveys (Ahlstrom et al., 1978). Uneven spatial distribution of recruitment for these highly residential species contributes to uneven distribution of adults.

Fluctuations in the proportion of particular species in the recreational catch do not always indicate increased abundance because they reflect both actual increases in the population and relocations by the fishery to previously unexploited areas. To reduce the influence of changes in fishing locations on the apparent abundance of blue rockfish, fisheries with clearly limited fishing areas were examined. The CPFV fishery at Año Nuevo, confined to a few isolated rocky outcrops, and the skiff fisheries in Santa Cruz and Monterey, limited to near shore areas within 10 km of port, were the most location specific. All three of these fisheries landed shallow water species from limited areas that were continuously exploited; thus they indicate temporal patterns of blue rockfish abundance.

In some periods, increased abundance of blue rockfish was nearly synchronous in both the northern and southern Monterey Bay areas. All areas experienced increased abundance of younger fish in 1969 or 1970 (Miller and Geibel, 1973) and again in 1981–84. In other periods, increased blue rockfish abundance was limited to certain areas. A marked increase in the catch of blue rockfish in both the Monterey skiff and CPFV fisheries in 1963 reflected young fish entering the fisheries in Monterey, but it had no corollary at Santa Cruz or Año Nuevo where blue rockfish catches continued to decline (Miller et al.[1]). In 1979, blue rockfish catches increased dramatically for Monterey CPFV's but not for skiffs; the fish were caught in Carmel Bay which is beyond the range of most skiffs. Therefore, in some periods the factors promoting strong recruitment of blue rockfish may be present throughout the Monterey Bay region, whereas at other times strong recruitment to the fishery appears to be very localized.

Fluctuations in the species composition of the catch from the CPFV and skiff fisheries in the Monterey Bay region reflect high variability in the number of young blue rockfish recruited. When fish of relatively strong year classes grow to acceptable size (after 3–4 years), fishing pressure of both skiff and CPFV fisheries focuses on blue rockfish and these strong year classes are removed in 2–5 fishing seasons. When blue rockfish are depleted, CPFV's target other species in deeper water (relieving some of the fishing pressure on the blue rockfish population), but skiffs continue to fish in the shallow areas, and the increased relative catches of other shallow water rockfish species confirm that blue rockfish are less available during those periods. The preference to fish for blue rockfish, appears to continue in all areas except the Santa Cruz CPFV fishery despite the development of new alternate fishing areas and depths, and Monterey CPFV's continue to target blue rockfish when available.

Multispecies Fishery

The multispecies nature of the recreational fishery has both positive and negative effects on the survival of the species involved. One positive effect is the tendency of the fishery to prey heavily on more abundant species and to shift to other species when one species becomes difficult to catch or when only small individuals are available. *Sebastes* is a very diverse genus, and different species occupy different benthic and midwater habitats from tide pools to depths >600 m. Changing fishing depth or area can relieve fishing pressure on a declining local population.

The tendency of the fishery to switch target species makes it difficult to quantify changes in abundance of some species because these changes can be hidden by increased abundance of alternate target species or shifts in location or depth fished. It is unclear whether yellowtail rockfish, the dominant species in the local Santa Cruz subarea, became scarce after 1983 or whether their proportion in the catch declined solely because of deeper fishing. Catch per hour at specific locations would be needed to evaluate these factors.

A negative effect of the multispecies fishery on the survival of some species comes from the incidental catch and discard of small individuals. Many discarded fish will not survive due to swim bladder expansion and resultant eversion of the stomach. The incidence of mortality for discarded fish increases from depths of more than 40 m (Culver, 1987) and is therefore more likely for CPFV's than for skiffs. Hook size confers some size selectivity, although there are some species with relatively small bodies and large mouths such as

[4] VenTresca, D. A., J. L. Houk, M. J. Paddack, M. L. Gingras, N. L. Crane, and S. D. Short. In press. Early life history studies of nearshore rockfishes and lingcod along the central California coast from 1987 through 1992. Calif. Dep. Fish Game, Mar. Res. Div. Admin. Rep.

[5] Adams, P. B. (Editor). 1992. Progress in rockfish recruitment studies. U.S. Dep. Commer., NOAA, NMFS Southwest Fish. Sci. Cent., Tiburon Lab., Admin. Rep. T-92-01, 63 p.

[6] Eldridge, M. B. 1994. Progress in rockfish recruitment studies. U.S. Dep. Commer., NOAA, NMFS Southwest Fish. Sci. Cent., Tiburon Laboratory, Admin. Rep. T-94-01, 55 p.

the rosy rockfish that are often discarded as being too small even when fully mature. Other species are caught and retained before they reach sexual maturity, decreasing the pool of spawners, and because the size of sexual maturity varies greatly from one species to another, later maturing species, such as black rockfish (50% of females are mature at 41 cm), are more vulnerable to recruitment overfishing than are similar appearing but earlier maturing blue rockfish (50% of females are mature at 29 cm) (Wyllie Echeverria, 1987; Reilly et al.[2]). The difficulty for anglers in distinguishing species within the group of 59 rockfish species found along the California coast (Lea, 1992) as well as the difficulty in avoiding incidental catch of non-targeted rockfish species, has led to management by CDFG of rockfish as a species complex in the recreational fisheries, with no size limits and a mixed species bag limit of 15 rockfish.

The affinity of certain species for specific habitats affects the catch of the skiff fishery and results in different species compositions on the two sides of the bay. Habitat requirements for some species such as grass rockfish are well known. Grass rockfish was most abundant in the skiff catch from Santa Cruz. It was caught primarily from eelgrass beds near Capitola in water <17 m deep in the early 1960's (Miller et al.[1]), but it declined in the catch after 1966 along with another very shallow dwelling species, black-and-yellow rockfish. This may reflect a decline in abundance or less fishing in water shallower than 20 m, and it does coincide with increased skiff catches of midwater blue rockfish from slightly deeper locations.

Kelp rockfish habitat requirements are also well known. Kelp rockfish was most abundant in the Monterey skiff catch because of its close association with giant kelp, *Macrocystis pyrifera*, (Van Dukhuizen, 1983; Hallacher and Roberts, 1985) which was more abundant near Monterey than near Santa Cruz. It became increasingly abundant in the Monterey skiff catch as kelp beds expanded from 0.8 km^2 to 4.7 km^2 between Monterey and Cypress Point in summer surveys of 1967 and 1989. It remained scarce near Santa Cruz where the kelp bed area decreased (Ecoscan[7]).

Differences in habitat availability across the bay are less apparent for some other species. White croaker and Pacific sanddab are both caught over shallow sandy sea floors, but Pacific sanddab is consistently more abundant in the Monterey subarea and less abundant in the Santa Cruz subarea where white croaker and brown rockfish are abundant. The greater proportion of white croaker and brown rockfish may be related to their greater tolerance for higher turbidity and water temperatures common in the more extensive shallow water zone near Capitola (Miller and Geibel, 1973).

The Monterey Bay region is in a zone where both northern and southern species occur, and for some species, the two sides of the bay reflect the latitudinal variation in distribution. Black rockfish constitutes a significant percentage of the recreational catch in Washington, Oregon, and northern California (Culver, 1987; Karpov et al., 1995), but in Monterey Bay it is near the southern end of its range. It is more abundant in both skiff and CPFV catches from the northern half of the Monterey Bay region, but it declined in the catch after 1967. It reappeared briefly in both Santa Cruz and Monterey skiff catches in 1985 which may indicate a pulse of recruitment of young fish in both areas; however, the pulse was brief in both areas. Black rockfish during 1987–91 showed signs of being heavily fished, and few of the fish had reached the size of sexual maturity (Reilly et al.[2]).

Olive rockfish was most abundant from Monterey county south to Ventura county and declined to the north in recreational catches surveyed by MRFSS (Karpov et al., 1995). Olive rockfish were more abundant in both the skiff and CPFV fisheries in the southern half of the Monterey Bay region than in the northern half. This may be a reflection of decreased abundance farther north, higher turbidity near Capitola, or of more extensive kelp beds in the Monterey area, since both olive and blue rockfish often aggregate near kelp beds (Love et al., 1991) and both decreased in abundance when kelp was experimentally removed (Bodkin, 1988).

[7] Ecoscan. 1989. California coastal kelp resources—summer 1989. Rep. for Calif. Dep. Fish Game (unpubl.).

Effect of Regulations

Regulations pertaining to recreational catches of rockfish have changed only once during the period covered by this report. In 1971 the limit for total rockfish retained per day decreased from 20 to 15 fish. CPFV logbook records indicated a decrease mean catch from 10 to 7 rockfish per angler day, however it lasted only 2–3 years, after which mean reported catch returned to nearly 10 rockfish per angler day (Fig. 2b). Catches are highest when blue rockfish are abundant, and during those periods adequate regulations are especially important to prevent excessive fish removal. During other periods, the catch for most anglers is less than the current limit and it is restricted by rockfish availability.

Lingcod has always been important to both the skiff and CPFV fisheries in the Monterey Bay region because of its large size. The proportion of lingcod declined after 1980 in the Monterey CPFV catch and after 1981 in the skiff catch from both areas. Two changes in lingcod regulations took place in 1980 and 1981. The limit on lingcod decreased from 10 to 5 fish per day in 1980, but catches remained high in 1980 and 1981. Most anglers caught <5 lingcod per day so the regulation had little net effect. Part of the decline after 1981 could be due to the 559 mm (22-inch) size limit instituted in 1981; however, the percentage of fish taken in northern California that were under this size declined from 44% in 1980 to 17% for 1981–89, a decrease of only 26% of the lingcod catch (Silberberg and Adams, 1993). In Monterey, the proportion of lingcod in the CPFV catch declined by 86% from 15 to 2% from 1981 to 1985 respectively and continued at that level from 1987 to 1991 (Reilly et al.[2]). There appeared to be a decline in overall abundance after 1981, in addition to the effect of the size limit. Lingcod is caught in both the recreational fisheries and the commercial trawl fishery, and because lingcod seasonally migrate to shallower

water for spawning, the same fish may occur within the range of both fisheries. Lingcod is caught in both the CPFV and skiff fisheries primarily in the fall and winter when they come into shallow water to spawn and the males remain to guard the eggs. Size limits apply only to the recreational fisheries. The size of lingcod retained has increased, but their relative abundance in the recreational catch has not increased.

Strategies to prevent the overfishing of lingcod and rockfish have not always been effective. In the case of lingcod and chilipepper, it may be due to combined commercial and recreational fishing pressures. Chilipepper declined in the CPFV catch and in catch per angler hour in 1990 and 1991 (Reilly et al.[2]). Declines in blue rockfish may be due to the combined effort of CPFV and skiff fishing. Fishing reserves designed to protect spawning stocks and enhance the recruitment of rockfish are a new strategy currently being investigated by the CDFG. Since rockfish are dispersed by ocean currents during the larval stage, it is assumed that locally protected resident populations of spawning adults could provide larvae for recruitment to a wide area. It is not yet known how large an area could be enhanced by a localized spawning reserve. Carr and Reed (1993) discussed some of the considerations to be made. Local habitat variations must be examined to determine appropriate locations for protection of adults of the desired species. Suitable habitat for recruitment of juveniles must be located in the area of dispersion, with some of that habitat inside the reserve for recruitment of future spawners of highly residential shallow water species and to protect juveniles of deeper dwelling species such as yellowtail and canary rockfish that live for several years as juveniles in shallow water. Inter-year variations in recruitment strength of rockfish, similar to those of blue rockfish, may delay the benefits of the reserves for several years and make it difficult to evaluate their success.

Conclusions

CPFV's from both Santa Cruz and Monterey have changed fishing areas when catches declined. They first attempted to maintain catches of shallow water blue rockfish by fishing in areas up to 30 km from port in the 1960's. Then they fished increasingly deeper locations, first at Santa Cruz at depths of 70 m for yellowtail rockfish in the 1960's, and later at both Monterey and Santa Cruz at depths of 100 m or more for chilipepper, bocaccio, greenspotted, and greenstriped rockfish. Deep-water fishing became more important than distant-water fishing by 1977. Most skiffs did not have the option of changing to deep water locations (several miles from port) as catches of blue rockfish declined. They continued to fish near shore on shallow water species. They provide a sensitive indicator of fishing conditions near port.

The supply of blue rockfish has undergone several periods of scarcity, separated by periods of relative abundance. High variability in recruitment success for rockfish species contributes to these fluctuations. Blue rockfish during these periods of abundance has been subjected to high fishing pressure, and its proportion in the catch has declined again after just a few years. Sampling the species composition of these fisheries only once every few years would not give a clear picture of these fluctuations. Catch per angler hour at specific locations is needed to track changes in abundance of other species.

There are differences in relative abundance of particular rockfish species between Monterey and Santa Cruz; some of these differences can be related to availability of specific habitats, and some may be due to latitudinal temperature differences. There are spatial differences in recruitment from these two areas during some periods. More can be learned by analyzing these areas independently than by treating them as one area.

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Skimmers: Their Development and Use in Coastal Louisiana

STEPHEN HEIN and PAUL MEIER

Introduction

The development of new and more efficient methods for harvesting seafood has been a part of the Louisiana fishing industry for many years. Louisiana fishermen, as some of the Nation's leaders of seafood production, have been the source of innovative ideas for the development and improvement of fishing gear for generations. Seines, originally adopted from France and other parts of Europe, were used in the early 1800's to harvest shrimp in Lake Pontchartrain; by 1878, seines and cast nets were the primary methods of shrimp harvest (Wurzlow, 1985).

By 1915–17, availability of gasoline engines, introduction of the otter trawl, and the advent of shrimp drying led to a greatly expanded market and shrimp fishery in Louisiana (Viosca, 1957). In addition, beam trawls, plumb-staff beam trawls, bib trawls, and many variations of them were employed by fishermen throughout the years, and in certain areas some are still in use.

Boats and trawls increased in size during the 1940's, and by the 1950's double-rig trawls were adopted. In the late 1950's, twin trawls were being experimented with in Louisiana and Texas. By the early 1970's, they were becoming more efficient and popular.

Butterfly nets (wing nets or "paupiers") were introduced in the 1950's and used on stationary platforms and on shrimp boats either under power or while anchored. A butterfly net consists of a square metal frame which forms the mouth of the net. Webbing is attached to the frame and tapers back to a cod end. The net can be fished from a stationary platform or a pair of nets can be attached to either side of a vessel. The vessel is then anchored in tidal current or the nets are "pushed" through the water by the vessel.

Vietnamese fishermen began moving into Louisiana in the early 1980's and introduced a gear called the "xipe" or "chopstick" net around 1983. The chopstick was attached to a rigid or flexible frame similar to the butterfly net; however, the frame mounted on the bow of the boat was attached to a pair of skids and fished by pushing the net along the bottom. As with butterfly nets, the contents of the net could be picked up and dumped without raising the entire net out of the water as is necessary with an otter trawl (Perret and Bowman, 1992). The chopstick beam trawl was designated an illegal gear for fishing in both inshore and offshore waters of Louisiana in 1984.

Development and Application

The latest gear to be developed and utilized in coastal Louisiana is the "skimmer" or "bay sweeper." This gear was developed around 1983 after much experimentation by shrimpers from the Barataria, La., area, including Will Rojas who helped pioneer the technique (Fritchey, 1989). Rojas and others who first used skimmer nets indicated that the primary reason for the development of the net was to catch the white shrimp, *Penaeus setiferus*, they observed jumping over the cork line as their trawls were being towed in shallow water. The skimmer net frame allows the net to be elevated above the water while the net is fishing, thus preventing shrimp from escaping over the top.

Rojas developed the idea from his son who had worked with other shrimpers using an earlier version of a similar gear used to catch shrimp in the shallow waters along the beach at Grand Isle, La. (Rojas[1]). Other fishermen report that this gear was developed from variations of the butterfly and chopstick nets;

Stephen Hein and Paul Meier are with the Louisiana Department of Wildlife and Fisheries, P.O. Box 189, Bourg, LA 70343. Views or opinions expressed or implied are those of the authors and do not necessarily reflect the position of the National Marine Fisheries Service, NOAA.

ABSTRACT—The origin, development, and utilization of the skimmer net is reviewed along with other historical shrimp gears used in coastal Louisiana. The skimmer was developed to catch white shrimp, Penaeus setiferus, *observed jumping over the cork line (headrope) of trawls being worked in shallow waters. A description of the gear is presented including basic components and various frame designs used by fishermen during its development. The advantages of skimmers over bottom trawls include: multiple use as both trawl and butterfly net (wing net), ease of deployment, increased maneuverability, reduction and greater survivability of bycatch, and ability to cover more area due to increased speed and continuous fishing capability. Disadvantages may include compromising vessel stability when stored upright on the deck, possible damage to water bottoms when improperly rigged, and limitation to a 12-foot (3.6 m) maximum depth due to size restrictions. The growing popularity of the skimmer net is evident by its introduction into North Carolina and inquiries from other southeastern Atlantic and Gulf coast states.*

[1] Rojas, W. 1994. Commercial shrimper, P.O. Box 433, Venice, LA 70091. Personal commun.

an early design consisted of trawls on frames with boards to open the net and a wheel in place of the skid (shoe) to roll along the hard sand bottom. Rojas indicated that many shrimpers were not convinced of the effectiveness of skimmer nets until some Vietnamese fishermen in Barataria, Empire, and Buras, La., successfully employed variations of his design after the chopstick nets were declared illegal. Owing to increased shrimp catch rates, less debris or bycatch, and lower fuel consumption experienced by commercial fishermen, use of skimmer nets quickly spread to other Louisiana areas.

Initially this gear was used by fishermen in Jefferson and western Plaquemine Parishes from 1983 through 1987. Use of this gear spread west into the communities of Dulac and Theriot in Terrebonne Parish around 1988. Increased use of skimmers then moved easterly to Lafourche Parish by 1990, to eastern Plaquemine Parish around Point a la Hache by 1990–91, then to St. Bernard Parish (Fig. 1). By 1992–93 widespread adoption of skimmer nets occurred in all of these parishes in southeastern Louisiana as reflected by skimmer license sales; also licenses were sold as far north as Ouachita and Franklin Parishes (Fig. 2, 3). Recently, use of this gear has been reported from North Carolina (Hines et al., 1993).

According to Louisiana Department of Wildlife and Fisheries interviews with shrimp fishermen and wholesale shrimp dealers, skimmer nets were outcatching trawls 3:1 in western Terrebonne Parish in the fall of 1988 (unpubl. data[2]). During this period shrimp appeared more active at night and remained buried during daylight hours. Skimmer nets were easier to maneuver between the numerous crab traps, while trawlers were generally limited to only daylight hours when they could more easily avoid crab traps to prevent them from fouling in the trawls and boat propellers. Due to efficient maneuverability and the capability of following shoreline contours, as opposed to the zig-zag method employed by single rig otter trawl fishermen to keep the net out of the vessel's prop wash, skimmers are more effective in small shallow ponds. Because skimmers are pushed, rather than pulled, prop wash is not a factor.

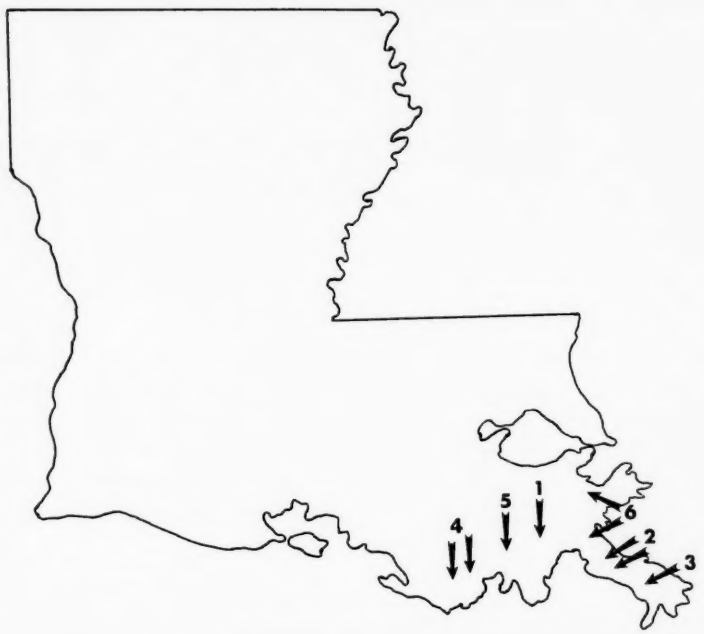

Figure 1. — Approximate dates, communities, and parishes where skimmers first began to be fished: 1 = Lafitte, 1983; 2 = Empire and Buras, 1984–85; 3 = Venice, 1987; 4 = Theriot and Dulac, 1988; 5 = Bayou Lafourche (Cut Off), 1990; and 6 = Point a la Hache (eastern Plaquemine Parish) and St. Bernard Parish, 1990–91.

Initially, skimmer nets were licensed as butterfly nets. In 1989, the Louisiana legislature made an unsuccessful attempt to ban skimmer nets via House Bill 669. This bill defined skimmer nets and would have prohibited their use. The introduction of the bill, the controversy surrounding the use of skimmer nets as an undefined gear, the perception that water bottoms were destroyed or altered by the bullet weights and skids, and the belief that this gear allowed excessive harvest of small shrimp discouraged many fishermen from investing in skimmers. The future of the gear was uncertain owing to the general perception that it would go the way of the chopstick net and be declared an illegal gear.

In September 1991, however, the Louisiana Legistlature in House Bill 533 legalized skimmer nets and defined them as "a net attached on two sides to a triangular frame and suspended from or attached to the sides of a boat, with one corner attached to the side of the boat and one corner resting on the water bottom. A ski and one end of the lead line are attached to the corner of the frame that rests on the water bottom and the other end of the lead line attached to a weight which is suspended from the bow of the boat."

House Bill 403 of the 1993 Louisiana legislative session further prohibited the tieing of individual skimmer nets together to exceed existing specifications and also prevented the use of any trawl in conjunction with a butterfly or skimmer net. Also, such nets were not supposed to impede or restrict normal navigation.

Since the legalization of skimmers in 1991 and the beginning of license sales

[2] Unpubl. data, 1988, from weekly shrimp reports on file with the La. Dep. Wildl. Fish., P.O. Box 189, Bourg, LA 70343.

by 1992, the number of skimmer licenses has increased while butterfly net and trawl licenses have decreased (Table 1). After Hurricane Andrew swept across coastal Louisiana in August of 1992, many butterfly net platforms and some trawl boats were simply abandoned rather than repaired. These and other circumstances, combined with the fact that many fishermen continue to convert to skimmers, has resulted in fewer sales of butterfly net and trawl licenses (Table 1).

Table 1.—Louisiana resident and nonresident commercial gear licenses sold. These do not represent numbers of licensed fishermen since most fishermen fish more than one net and must have a license for each net. Source: LDWF License Section.

Year and type	Skimmer	Butterfly net	Shrimp trawl
Resident			
1991	0	7,982	14,949
1992	3,748	4,746	13,866
1993	4,583	3,809	11,349
Nonresident			
1991	0	48	3,757
1992	42	32	3,454
1993	56	24	3,216

The introduction of the skimmer has had a major impact on the shrimp fishery in Louisiana. A series of public meetings along the Louisiana coast were sponsored by the Governor's Task Force on Shrimp Management during March 1994. Results of a questionnaire distributed during those meetings indicated that the skimmer was the second most common shrimping gear (29%) following the otter trawl (56%), which remains the primary gear. About 84% of the fishermen who use skimmers believe they should remain a legal gear, and of all respondents, regardless of their primary gear, 52% agreed skimmers should remain legal, 43% indicated they should be illegal, and 5% had no opinion. Most skimmer fishermen surveyed (97%) work inshore waters and 71% use vessels of 26–44 feet (7.8–13.2 m) in length, suggesting its primary use is in shallow water areas by the small to medium vessel fleet (unpubl. data[3]).

[3] Unpubl. data, 1994, from questionnaires by the Louisiana Governor's Task Force on Shrimp Management on file with the La. Dep. Wildl. Fish., P.O. Box 98000, Baton Rouge, LA 70898.

Figure 2. — Resident skimmer net gear licenses sold for 1992 (total = 3,748). Normally only two gear licenses are sold per fisherman.

Figure 3. — Resident skimmer net gear licenses sold for 1993 (total = 4,583). Normally only two gear licenses are sold per fisherman.

Gear Description

Of all current legal gears, skimmers most closely resemble butterfly nets. Both gears are "pushed" alongside the vessel, always fished in pairs (except stationary butterfly nets) on the sides of the vessel, held open by some form of metal framework, deployed and retrieved in a similar manner, fished continuously with little or no interruption in fishing time, and subjected to similar legal restrictive measures in mesh size and net dimensions. The gears differ in frame design, the necessity of some form of weight to spread the skimmer net open, a "tickler" chain and lead line on the bottom of the skimmer, and the need of a skid or "shoe" for the skimmer's outer leg to allow operation along the water bottom. The skid is an optional feature on the butterfly net since it is not normally fished along the bottom.

To effectively handle the gear, the vessel must possess some style of A-frame or superstructure to which the net frames are secured, generally in the vessel's forward one-third to one-half (Fig. 4). A short shaft capable of swiveling up and down is located at the base of the A-frame onto which the net frames slide and are secured by a bolt or pin. Net frames are raised and lowered by winches and pulleys and folded against the vessel fore or aft for transit.

The basic components of the skimmer gear include net frames, nets, heavy weights, skids or "shoes," winches, and tickler chains. The net frame is usually constructed of schedule 80 steel or aluminum pipe or tubing and is either L-shaped (with an additional stiff leg) or a trapezoid design as one of the original skimmer frames was constructed

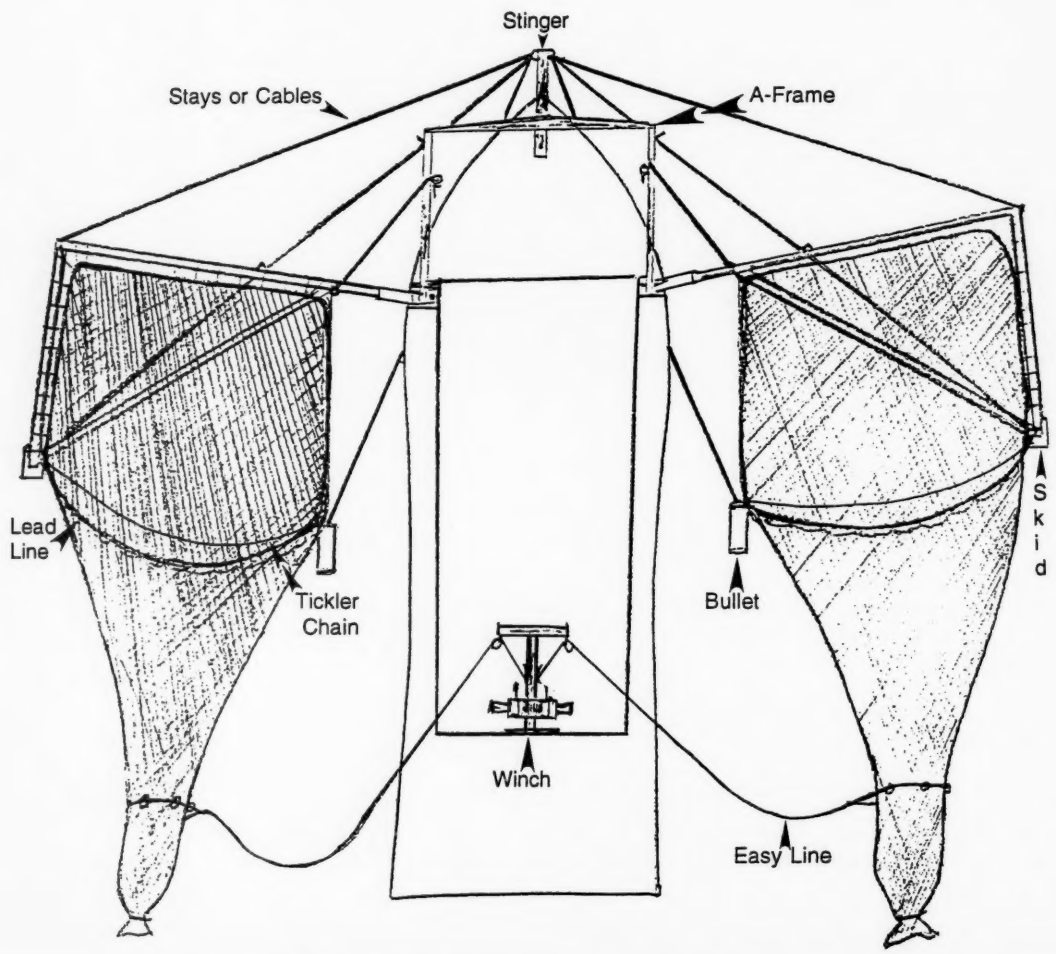

Figure 4. — Illustration of skimmer nets deployed on a vessel.

(Fig. 5). The upper portion of the net frame accounts for the distance from the water to the freeboard of the vessel (Fig. 6). When net frames are deployed or "working," they are aligned perpendicularly to the vessel and cocked or tilted forward and slightly upward. This position allows the net to fish better and reduces the chance of the leading edge of the skid digging into the bottom and subsequently damaging the gear. The frames are maintained in this position by two or more stays or cables to the bow. The horizontal portion of the frame includes a 24-inch (61 cm) maximum legal allowable clearance from the side of the vessel plus the 16-foot (4.8 m) maximum legal allowable width of the net (Fig. 6). The outer leg of the frame is held in position with a "stiff leg" to the horizontal pipe and determines the maximum legal depth (12-feet [3.6 m] allowed) at which each net is capable of working (Fig. 6). To the bottom of the outer leg is attached the skid or "shoe" which allows the frame to ride along the bottom, rising and falling with the bottom contour. Before skimmers were legally defined to require a 90° angle on the 16 × 12-foot (4.8 × 3.6 m) frame, early rigs had a "kickout" which was an angled portion of the frame on the outside corner, extending the width of the net allowing it to fish more water and also to flex more easily when the net came into contact with steep bayou banks.

Skids differ greatly in design and size according to area fished, vessel and frame size, and fisherman preference, although aluminum plate is most often used. The general design is flat or U-shaped with an upturned leading edge. The most frequent skid sizes encountered were 3 feet × 18 inches (0.9 m × 45.7 cm) and $3^1/_2$ feet × 24 inches (1.1 m × 61 cm), though smaller and larger ones were noted. One end of the tickler chain and net is usually attached to the skid although variations of this method do exist.

Earlier forms of skimmer frames had an inside leg which was shorter than the outer leg, thus allowing the frames to be raised and lowered in shallow water without bending or burying the inside leg in the bottom sediments (Fig. 5). The inside leg has been largely replaced by a heavy weight to which the other ends of the tickler chain and bottom of the net are attached. Depending upon geographical location the weight is referred to by fishermen as a "bullet," "dummy," or "torpedo." The primary purpose of the bullet is to help spread the net vertically and horizontally. Attempts to replace the bullet with skids, dummy doors, and trawl boards have proven largely unsuccessful, and the bullet remains the primary device used.

The amount of weight used varies with vessel size, engine horsepower, bottom type, mesh, and net size. While weight can range upwards to 400 pounds (180 kg), 90–200 pounds (40.5–90 kg) are most commonly encountered. Bullets are generally constructed from a length of round pipe filled with cement and beveled upward (ski-like) on the leading edge. Some fishermen have replaced the pipe with a flat steel plate but have retained the beveled leading edge. Pipe diameter and length, as well as plate size and number, vary considerably.

The weights are deployed and retrieved with winches using cable or rope. They are commonly tethered to the bow near the waterline or in some situations to a "stinger" or bow extension. When set, the heel of the bullet is in the same vertical plane as the frame and slightly forward of the net, reducing the tendency to burrow.

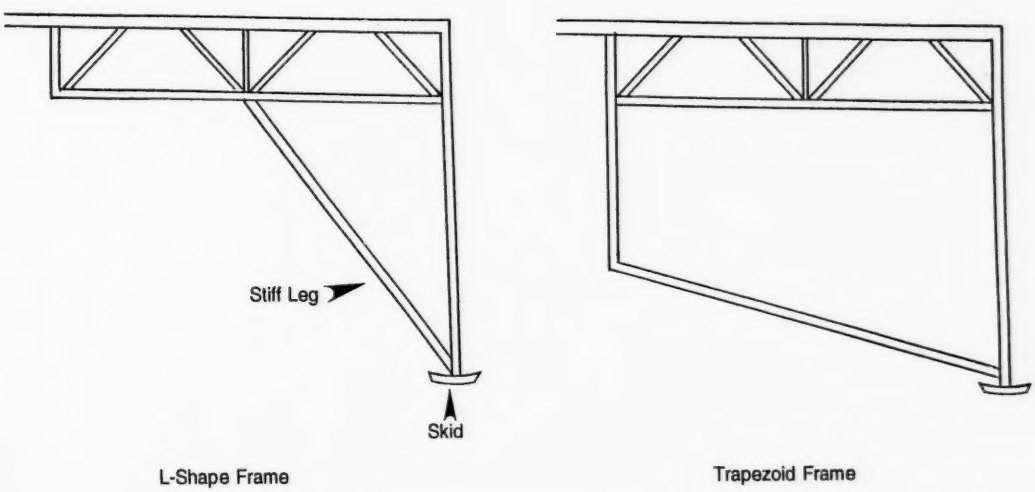

Figure 5. — Basic skimmer net frame designs.

Tickler chains and lead lines comprise the bottom of this gear. The lead line cannot exceed 28 feet (8.5 m). The chain is commonly 1/8 or 3/16 inch (0.3 or 0.5 cm) but may be 1/4 inch (0.6 cm) or more for larger vessels; lighter chains are used on soft or muddy substrates and heavier chains on hard or sandy bottoms. Depending on areas fished and fishermen preference, the chain is usually set 12–18 inches (30.5–45.7 cm) shorter than the lead line so that it rides slightly ahead of the net. The chain is set closer to the lead line for white shrimp than for brown shrimp, *Penaeus aztecus*. Lead lines resemble those of trawls and may contain additional "loop" chains or mud rollers (depending upon area fished). Some boats use a "four point" attachment method to secure the webbing to the frame, where only the four corners of the net are attached to the corners of the frame and to the bullet weight, allowing the net to fish several feet behind the frame. The farther back the net is set the closer it remains to the bottom and the better it will fish in deep water. The webbing may also be attached directly to the frame.

Nets are usually constructed of traditional knotted nylon webbing. Knotted and knotless polyethylene have recently gained attention and are believed to be stronger, perform more efficiently, and reduce fuel consumption and bycatch (Fritchey, 1989). Net type consists of a two- or four-seam design and contains various amounts of "setback" similar to conventional trawls. The two-seam nets are more easily built and somewhat cheaper in cost but have a tendency to "pocket" the catch and restrict its path to the cod end. Adjustments in design often offset this tendency.

Net patterns, preference of mesh, twine size, hanging, and length are diverse. A generic net would be about 350 meshes long, have a 120- 170 mesh cod end, and consist of 1 1/2 to 1 3/4 inch (3.8–4.5 cm) mesh of number nine twine for the first 100 meshes, 1 3/8 to 1 1/2 inch (3.5–3.8 cm) mesh of number seven twine for the next 200–250 meshes and 1 1/4 to 1 3/8 inch (3.2–3.5 cm) mesh of number fifteen twine for the cod end. The stronger twine in the mouth of the net reduces the chance of tearing from the constant strain on this portion of the net.

There is usually more webbing in the skimmer net than in a standard trawl, allowing the fisherman to pick up the tail of the skimmer and dump his catch while most of the net remains in the water and continues to fish. Also, the lead line is prevented from rising off the bottom and allowing shrimp to escape underneath. According to Bobby Boudreaux[4], there is normally about 40

[4] Boudreaux, R. 1994. Net maker, 105 Rogers Street, Lafitte, LA 70067. Personal commun.

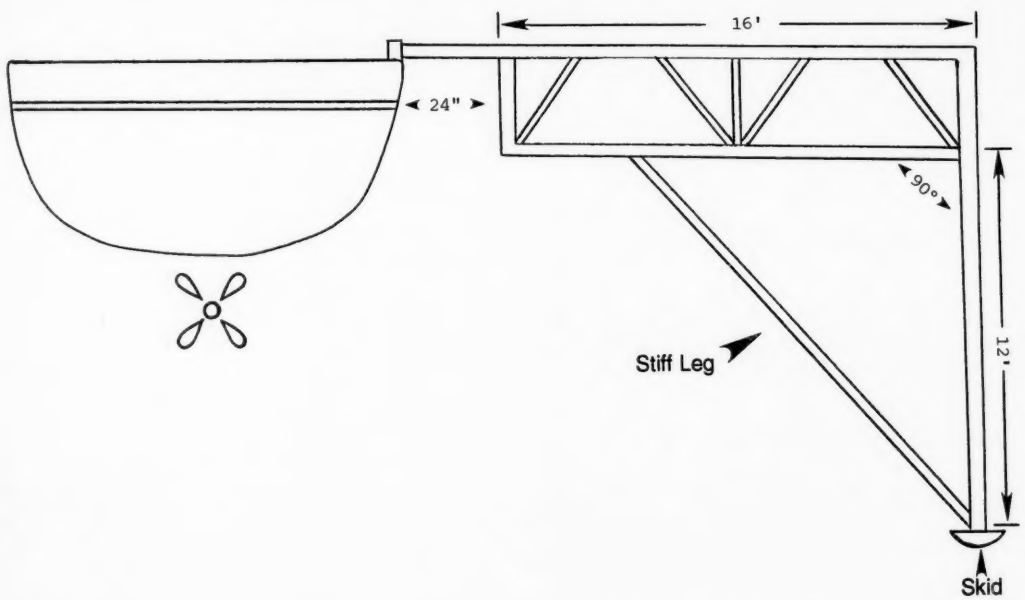

Figure 6. — The horizontal frame must have a maximum allowable distance of 24 inches (61 cm) from the side of the vessel according to Louisiana law.

pounds (18 kg) of number seven webbing of 1 1/2 inch (3.8 cm) mesh in a set of 16 × 12-foot (4.8 × 3.6 m) skimmer nets while there is about 25 pounds (11.3 kg) of number seven webbing of 1 1/2 inch (3.8 cm) mesh in a 50-foot (15 m) trawl.

An easy line, or lazy line, encircles the cod end through a series of rings sewn onto it. The rope typically is run through a pulley or block on the vessels' rigging and raised via a winch (electric, hand, or hydraulic). A recent feature is a 5-foot (1.5 m) nylon zipper sewn onto the top of each net just ahead of the cod end allowing fishermen to more easily remove bulky or unwanted items from their nets. Different types of fish excluder devices are used by some fishermen to reduce bycatch.

Operation

While skimmers are pushed alongside the vessel, the otter trawl is towed at various distances behind the vessel using a pair of boards to spread the net. Single rig trawls are towed so as to maximize net spread while keeping them out of the prop wash, generally in a zig-zag or semi-circular pattern. By contrast, the opening of the skimmer net is always in front of the vessel's prop wash.

Trawls are deployed overboard followed by the tickler chain and a set of doors. Water resistance forces the doors to spread and open the webbing. Care is taken to avoid tangles and flipped boards. Tow lines are then payed out until the desired length is achieved. This process is reversed to retrieve the gear and results in some loss of actual fishing time, plus additional labor.

Skimmers are deployed by lowering the frames and bullets to the desired fishing depth and releasing the tickler chain and webbing overboard. Only the cod ends are retrieved to maximize fishing effort.

Both otter trawls and skimmers can be legally fished in daylight or darkness. Although versatile, each gear is restricted by its design and method of operation. Fishermen representing each staunchly defend their gear, although skimmers appear to have many advantages over traditional otter trawls including:

1) They can replace the need for multiple fishing gears, can be used instead of the trawl, and are capable of being used as butterfly nets by adding weight to the bullet.

2) They eliminate the need for a "test" net. The gear itself is deployed and cod ends are checked for catch. If dissatisfied with the results, the fisherman then raises the rig and travels to a different area. This gives the fleet more mobility and efficiency.

3) The gear continues to fish while cod ends are emptied. This gives additional fishing time and reduces work involved in retrieving the entire rig.

4) Cod ends can be checked more easily and more often so that the catch is dumped much more often. This results in a reduction in bycatch (Hines et al., 1993) and may eliminate the need of "salt" boxes.

5) Better survivability of nontarget organisms is achieved. Fish, crabs, and other animals are not dragged around and packed in heavy concentrations for long periods. Since return to the water occurs behind the openings of the nets, chances of bycatch recapture are reduced.

6) Higher quality shrimp are produced. Frequent dumping of the catch prevents damage to shrimp from crabs, fish, and debris which can occur during longer trawl tow times.

7) They can be effectively fished in shallow nursery habitat, generally consisting of small bays, bayous, and ponds, as well as larger open bays.

8) They are more maneuverable and can more easily avoid snags and crab traps. The need to zig-zag, as with the single rig otter trawl to keep the net out of the prop wash, is reduced.

9) They can cover an area quicker and more effectively. Entire shorelines can be swept vs. only portions being covered by a conventional trawl.

10) There are no TED restrictions. If only skimmer nets or butterfly nets are rigged for fishing, the shrimper is exempt from the use of a TED.

11) Safety is improved as there are no heavy doors in rigging.

12) The entire water column up to 12-feet can be fished. This is especially effective for white shrimp.

Some disadvantages of skimmers include:

1) They are limited to the depth fished by the 12-foot maximum depth of the outer leg, although they can be used as butterfly nets in deeper water.

2) They may require more vigilance, especially at night near shorelines and obstructions.

3) If the gear is improperly tuned or poorly designed for the vessel, skids and bullets are thought to cause bottom damage. There have also been complaints of prop damage to the bottom in shallow areas.

4) When nets are stored upright on the deck they may affect vessel stability and safety in rough seas.

In 1990, University of North Carolina Sea Grant Program researchers initiated a study of the skimmer in North Carolina waters (Hines et al., 1993). They compared a pair of 16 × 12-foot (4.8 × 3.6 m) skimmers on one vessel to a pair of 35-foot (10.5 m) otter trawls on another vessel. Tow time for trawls was 90 minutes vs. 30-minute intervals for the skimmers. Due to various problems, results during the brown shrimp season were mixed. After fine tuning the rigs for the white shrimp season, Hines et al. (1993) reported that bycatch for the entire study was about 12% less per unit of time with the skimmers and 30% less for comparable time during the white shrimp season. During that season, the fish to shrimp ratio was about 1:1 for skimmers and 8:1 for otter trawls. Skimmers were found to be extremely efficient and outfished otter trawls by 5:1.

Catch was culled immediately following dumping of the cod end. They found that the shorter culling time gave higher survival of bycatch and shrimp, resulting in a better quality catch. Comparison of average survival rates for selected species from trawl and skimmer bycatch indicated 12 of 16 finfish species and brown, white, and pink shrimp, *Penaeus duorarum*, had greater survival in the skimmers (Table 2) (Hines et al., 1993). Some initial tests with the Florida fish excluder appeared effective in further reducing bycatch (Hines et al., 1993).

In addition to the advantages of skimmers over otter trawls already stated, the

North Carolina study noted that skimmer costs were comparable to trawls, 5–15% better fuel efficiency was recorded, and greater ground coverage (at about 2.5 knots, it was faster than the otter trawl) was noted. However, skimmers tended to foul with seagrass and seaweed and did not fish well on highly irregular bottoms. The study also documented increased survival of the three predominant shrimp species from the skimmer (Hines et al., 1993). However, if undersized shrimp were culled overboard it is still unknown what long-term survival would be achieved.

Discussion

Some areas in coastal Louisiana have subsided and eroded so greatly that the skimmer has become one of the most effective methods available to harvest shrimp. Marsh subsidence along with erosion of shorelines and canal banks eliminate the possibility of using traditional gear (butterfly nets and trawls) in some areas. Additionally, mud lumps, detritus, and marsh vegetation often congest trawls being worked in shallow ponds where marsh deterioration is prevalent. Skimmers can be set to fish above the bottom debris making them more efficient at catching shrimp under these conditions.

Continued marsh degradation has actually increased production with the introduction of nutrients to estuaries, increased marsh/water interface, and has contributed to shrimp landings averaging 109.4 million pounds (heads-on weight) annually in Louisiana over the past 10 years (1984–93). This condition will be short-lived as marsh deterioration continues, and eventually production will decline as the marsh vegetation and substrate which provides food and shelter cease to exist (Perret and Melancon, 1991).

Although the gear has its proponents, many fishermen we have interviewed dislike it because of potential water bottom damage and destruction of juvenile shrimp. Personal communication with numerous fishermen, net makers, and others in the industry indicated they felt most shrimp no longer reached the larger bays and open Gulf of Mexico, regarded as the traditional fishing grounds, as they did historically. Also, they believed nursery areas should be protected, but were not in favor of restricting "their" fishing grounds. Most of the skimmer fishermen interviewed said while they did not like to use the gear, their competitive nature dictated that they use it.

This gear has proven to be an effective and efficient method of harvesting shrimp with numerous advantages over the more conventional methods. However, its adaptability for use in extremely small, shallow, northerly portions of the estuary should be reviewed. As one state fisheries agent phrased it, "skimmers may be too efficient. The quest for efficiency is what keeps the fishing industry alive, but where do you draw the line? After all rotenone is a poison, a more efficient way of taking fish, but we don't allow that. There must be limits to efficiency; yet if we ban the skimmer will we be legislating for inefficiency, and will that kill us down the road?" (Fritchey, 1989).

Resource management strategy often leads to prohibition of efficient gear owing to real and/or perceived overexploitation. Often decisions are based upon competition among user groups for the same resource rather than documented overexploitation by a specific gear.

Future resource competition may require some additional regulation of this gear; presently, no biological data exists to indicate such a need. Rather, other management methods should be more closely examined, such as limited entry, license fee increases, stricter penalties for violations, and sanctuary establishment.

Compared to more traditional shrimping methods, the skimmer is still in its infancy. As fishermen fine-tune their rigs, additional advancements are possible. Presently, there appear to be as many ideas on adaptations and improvements of the skimmers as there are skimmer fishermen.

Table 2.—Comparison of average survival rates for selected finfish and shellfish species collected by otter trawl (control) and skimmer trawl in the Straits of Marshallberg and the North River, N.C., in 1991. Survival rates assume a tow time of 90 minutes for the otter trawl, 30 minutes between retrievals for the skimmer trawl tailbag, and immediate culling of the catch after placement of the catch in the culling tray. Source: Hines et al. (1993).

	Otter trawl		Skimmer trawl		
Species	N[1]	% Alive	N[1]	% Alive	Relative change in survival (%)[2]
Blue crabs	12	94.28	12	92.33	−1.95
Pinfish	13	76.23	18	87.24	+11.01
Pigfish	10	68.11	11	90.91	+22.80
Pink shrimp	4	64.43	4	89.39	+24.96
Atlantic croaker	6	63.03	11	86.36	+23.33
Brown shrimp	5	60.67	6	64.52	+3.85
Weakfish	2	58.33	3	42.86	−15.47
Atlantic spadefish	3	50.00	3	100.00	+50.00
White shrimp	2	34.27	6	56.02	+21.75
Spot	14	33.79	21	70.28	+36.49
Bluefish	3	33.33	3	25.00	−8.33
Silver perch	3	33.33	6	36.67	+3.34
Atlantic menhaden	7	30.10	14	49.60	+19.50
Sea robins	5	26.67	5	60.00	+33.33
Silver jenny	6	20.83	5	46.31	+25.48
Atlantic thread herring	9	17.11	20	8.30	−8.81
Lizardfishes	5	10.00	8	6.25	−3.75
Bay whiff	9	0.00	3	8.33	+8.33
Spanish mackerel	8	0.00	12	7.64	+7.64
Anchovies	4	0.00	13	0.96	+0.96

[1] N = Number of tests.
[2] Positive change means better survival in skimmer trawl.

Acknowledgments

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Preferred paper length ranges from 4 to 12 printed pages (about 10-40 manuscript pages), although shorter and longer papers are sometimes accepted. Papers are normally printed within 4-6 months of acceptance. Publication is hastened when manuscripts conform to the following recommended guidelines.

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Submission of a manuscript to *Marine Fisheries Review* implies that the manuscript is the author's own work, has not been submitted for publication elsewhere, and is ready for publication as submitted. Commerce Department personnel should submit papers under a completed NOAA Form 25-700.

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In style, the *Marine Fisheries Review* follows the "U.S. Government Printing Office Style Manual." Fish names follow the American Fisheries Society's Special Publication No. 12, "A List of Common and Scientific Names of Fishes from the United States and Canada," fourth edition, 1980. The "Merriam-Webster Third New International Dictionary" is used as the authority for correct spelling and word division. Only journal titles and scientific names (genera and species) should be italicized (underscored). Dates should be written as 3 November 1976. In text, literature is cited as Lynn and Reid (1968) or as (Lynn and Reid, 1968). Common abbreviations and symbols such as mm, m, g, ml, mg, and °C (without periods) may be used with numerals. Measurements are preferred in metric units; other equivalent units (i.e., fathoms, °F) may also be listed in parentheses.

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